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Soil Moisture

A THREE-PART GEOMETRIC MODEL TO PREDICT THE RADAR BACKSCATTER FROM WHEAT, CORN, AND SORGHUM

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16. Abstract

A model to predict the radar backscattering coefficient from crops must include the geometry of the canopy. Radar and ground-truth data taken on wheat in 1979 indicate that the model must include contributions from the leaves, from the wheat head, and from the soil moisture. For sorghum and corn, radar and ground-truth data obtained in 1979 and 1980 support the necessity of a soil moisture term and a leaf water term. The Leaf Area Index (LAI) is an appropriate input for the leaf contribution to the radar response for wheat and sorghum, however the LAI generates less-accurate values for the backscattering coefficient for corn. Also, the data for corn and sorghum illustrate the importance of the water contained in the stalks in estimating the radar response.

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ABSTRACT

A model to predict the radar backscattering coefficient from crops must include the geometry of the canopy. Radar and ground-truth data taken on wheat in 1979 indicate that the model must include contributions from the leaves, from the wheat head, and from the soil moisture. For sorghum and corn, radar and ground-truth data obtained in 1979 and 1980 support the necessity of a soil moisture term and a leaf water term. The Leaf Area Index (LAI) is an appropriate input for the leaf contribution to the radar response for wheat and sorghum, however the LAI generates less accurate values for the backscattering coefficient for corn. Also, the data for corn and sorghum illustrate the importance of the water contained in the stalks in estimating the radar response.

NOMENCLATURE

Symbol	SI Units	Description
A_{ill}	m^2	Area illuminated by radar
A_{leaf}	----	Empirical coefficient for leaf contribution to predicted radar backscatter
B_{head}	----	Empirical coefficient for wheat head contribution to predicted radar backscatter
B_{stalk}	----	Empirical coefficient for stalk contribution to predicted radar backscatter
C	----	Empirical coefficient for vegetation contribution to predicted radar backscatter
C_{soil}	----	Empirical coefficient for soil contribution to predicted radar backscatter
D	nepers m kg^{-1}	Empirical attenuation coefficient for attenuation due to plant water
D'	nepers m kg^{-1}	Empirical vegetation attenuation coefficient with no angle dependence
D''	nepers m^2 kg^{-1}	Empirical vegetation attenuation coefficient with no angle dependence
DWT	kg m^{-2}	Area normalized plant dry weight
DWT_{head}	kg m^{-2}	Area normalized wheat head dry weight
E	nepers	Empirical attenuation constant for attenuation due to leaves

E'	nepers	Empirical attenuation constant for attenuation due to leaves with no angle dependence
E_1	----	Leaf attenuation term in model
E_2	----	Stalk attenuation term in model
H	m	Crop canopy height
HDWT	kg	Wheat head dry weight
HWWT	kg	Wheat head wet weight
LA	m^2	Plant sample green leaf area
LAI	$m^2\ m^{-2}$	Leaf Area Index
m_s	$kg\ m^{-3}$	Volumetric soil moisture content
N	m^{-3}	Number of scatterers per unit volume
PD	plants m^{-2}	Planting density
PDWT	kg	Plant sample dry weight
PPH2O	%	Plant percentage moisture content by wet weight
PWWT	kg	Plant sample wet weight
P_i	W	Incident power of radar
P_r	W	Average received power
Q	----	Total attenuation cross-section for one plant canopy scatterer

S	$W\ m^{-2}$	Incident radar power density
SDWT	kg	Soil sample dry weight
SS		Number of plants in plant sample
SWWT	kg	Soil sample wet weight
SVOL	m^3	Soil sample volume
W	$kg\ m^{-3}$	Volumetric normalized plant water content
W_{head}	$kg\ m^{-3}$	Volumetric normalized head water content
W_{stalk}	$kg\ m^{-3}$	Volumetric normalized stalk water content
WWT	$kg\ m^{-3}$	Plant sample wet weight normalized by volume
z_o	m	Canopy thickness
α	nepers m^{-1}	Power attenuation coefficient per unit length
α_{leaf}	nepers m^{-1}	Power attenuation coefficient per unit length due to leaves
α_{stalk}	nepers m^{-1}	Power attenuation coefficient per unit length due to stalk
η	m^{-1}	Radar cross-section per unit volume
θ	degrees	Radar incidence angle
ρ	----	Correlation coefficient between predicted and observed backscatter coefficients

σ^o	m^2	Backscatter cross section coefficient
σ^o_{head}	$m^2\ m^{-2}$	Backscattering cross section coefficient for wheat head contribution
σ^o_{leaf}	$m^2\ m^{-2}$	Backscattering cross section coefficient for leaf contribution
σ^o_{obs}	$m^2\ m^{-2}$	Observed backscattering cross section coefficient
σ^o_{pred}	$m^2\ m^{-2}$	Predicted backscattering cross section coefficient
σ^o_{soil}	$m^2\ m^{-2}$	Backscattering cross section coefficient for soil contribution
σ^o_{stalk}	$m^2\ m^{-2}$	Backscattering cross section coefficient for stalk contribution

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1.0 INTRODUCTION

1.1 Purpose of Research

The accurate inventory of crops and the estimation of yields are two inputs necessary for food-resource planning and management. Radar remote sensing is a valuable tool that can be used to measure and predict crop conditions and types. Before this tool can be applied, however, the interaction between the crops and underlying soil and the radar sensor must be understood. Radar response is influenced by many parameters, some of which are of interest and some of which only complicate the backscattering behavior. The goal of this research is to accurately model, with the least amount of complexity, interaction between radar and crop. The model should then be helpful in determining crop and field conditions.

1.2 Overview of Data to be Presented

The data analyzed were acquired in two separate years, April to September, 1979, and June to September, 1980, using the Microwave Active Spectrometer (MAS) 8-18/35 scatterometer (Ulaby, et al., 1979) developed by the University of Kansas Remote Sensing Laboratory. The experiments were conducted in conjunction with Kansas State University at the Evapotranspiration Research Field, located 14 km southwest of Manhattan, Kansas. In 1979, radar data were taken at 8.6, 13.0, 17.0, and 35.6 GHz. Data were measured at three different look angles and three

polarization configurations (HH, VV, and HV). The number of spatial samples varied with angle from 20 samples at a 30-degree incidence angle to 15 samples at 50 degrees, to 10 samples at 70 degrees. Three crops were observed: the first was hard red winter wheat (Triticum aestivum L.) from May, 1979, through June, 1979, and the other two crops were sampled from June, 1979, to September, 1979, and were corn (Zea mays L.) and sorghum (Sorghum bicolor L.). Two wheat fields and six each of corn and sorghum were measured. Besides the radar data, ground-truth parameters such as plant height, plant wet- and dry-weights, leaf area index (LAI), soil moisture, planting density, and crop yield were measured.

In 1980, the data sets taken focused on one look angle only, 50 degrees, in order to remove one variable from the modeling process. The same frequencies and polarizations were measured, and the number of fields was decreased to three each of sorghum (Sorghum bicolor L.) and corn (Zea mays L.). More data sets and spatial samples for each field were obtainable by reducing the number of fields and incidence angles sampled. The number of spatial samples was increased to 25 points at 50 degrees, thereby reducing the measurement uncertainty. The number of data sets was increased from about six per field to 25 per field, and the external calibrations were more frequent. As a result, the 1980 data sets were more easily modeled and were analyzed first.

Another difference in the 1980 experiment was that the ground-truth measurements were more extensive. The plant parameters were measured both by layers and by plant parts. The sorghum was divided into two layers and the corn was divided into two and subsequently three layers.

Within a layer, the LAI and the wet- and dry-weights of the plant parts were measured separately in order that the distribution of water in the plant could be examined. The parameters were also totaled so that the same ground-truth parameters were available as in 1979.

1.3 Overview of Model Development

In order to model the interaction between microwave radar and the chosen crops, the model must have as inputs crop- and soil-related variables that effect changes on the radar backscattering. The variables must cause a significant change in the radar response and must be in some way accurately quantified. In a simplified model, there are two driving forces in determining the radar backscattering from a target. First, the target's dielectric constant will determine how much energy will be reflected or absorbed. At the frequencies of interest, the water content and mobility of the water present are the major factors in determining the dielectric constant of the crop canopy and the soil beneath.

The second factor influencing the radar return is the geometry of the target. A "smooth" target will reflect energy away from the transmitter, just as light bounces off a mirror. A target with a rougher, more jagged surface will scatter more energy back to the transmitter. Also, the target's geometry can cause different backscattering with different polarizations. There can be more absorption or scattering of energy in one plane than in another.

Measurable parameters of the crop canopy and the soil, which correlate to changes in the dielectric constant and the geometric properties, should be used as the inputs to the model. The remaining question is which to use. Knowledge about the target helps to narrow the choices. First, during the early part of the growing season, the target consists of mostly bare soil. The fields have been plowed and planted, and left for germination and emergence to take place. One part of the model must take into account the bare soil contribution to the backscattering.

Accurately predicting the radar return from bare soil is a difficult problem in itself. The soil type and water content affect the dielectric constant of the soil, with increasing water and sand content causing a higher dielectric constant (Schmugge, et al., 1974). The roughness of the field will also influence the backscattering by changing the angular distribution. Ulaby, Bradley, and Dobson (1979) have shown that the radar response varies exponentially with soil moisture. The simplest first approximation for the backscattering from the soil is a linear relationship between the volumetric soil moisture content m_s and the backscattering contribution from the soil. The roughness dependence is omitted to keep this term of the model simple. The change in roughness is relatively slow and the canopy is expected to mask the soil moisture term. Once the crop is sizable, the soil moisture term becomes negligible, so changes in the roughness have little effect.

The next contribution of importance comes from the leaves. The leaves are important because they reflect energy as well as block the

scattered energy from the soil. The leaves are mostly water; therefore, their dielectric constant should be fairly high and the leaves should strongly influence the radar return. As the leaf coverage goes up, the contribution from the soil should go down and the leaf backscattering should go up. The choice of variable to use as the input for the leaf contribution is problematic. For optical remote sensing, the choice of percentage of leaf coverage is as a variable because the leaves are impenetrable at optical wavelengths. With microwave radar, though, the radar can "see" through the leaves and be affected by the lower leaves. The appropriate input for the model must measure the total area of plant leaves, and the variable LAI does just that. One final consideration with this part of the model is the layering of the leaves. Because the leaves are not all in the same plane, leaves can block each other. Somehow, the model must take this layering into account.

Although the leaves account for the greatest area intercepted by the radar, they do not contain the majority of the water in the canopy. Depending on the crop and the stage of growth, the stalk and the cob (or head) contain most of the water present. In the top third of a fully grown corn plant, the leaves contain as much as 75 percent of the water in the layer. By contrast, when discussing the whole plant, the stalk-plus-cob contains 75 percent of the total water in the plant. Sorghum also has this sort of weighting; the leaves account for only 30 to 35 percent of the total plant water. From these results, the model must include a contribution from the stalk-plus-fruit.

The ground truth obtained in 1979 was limited, and there is a limited choice of parameters available to model both years. The best

parameter to use for the stalk-plus-fruit term would be the water content of just those parts, normalized over the areal extent of the crop. Since this measurement was not made in 1979, some other parameter with correlation to the stalk moisture must be used. Both the normalized plant dry weight (kg of dry matter/m^2 of field) and total normalized plant water content (kg of water in plant/m^2 of field) were tried, and the best results were attained by using the plant water content.

1.4 Preliminary Conclusions

The model, when applied to the three crops over two years, did increase the knowledge and understanding of crop conditions. For all three crops, the model accounts for the major trends over the growing seasons. In most cases it exhibits the correct frequency and polarization trends. Due to the relatively small number of fields studied, the ability of the model to predict yield and planting density remains mostly untested.

2.0 DATA ACQUISITION AND CALIBRATION

2.1 Ground-Truth Parameters

In 1979, the number of ground-truth data taken was limited. The model has to account for the main sources of scattering in order to accurately predict the radar interaction. At the same time, only certain physical parameters of the crops can be measured easily. As a result of these two factors, the following parameters were measured:

1) Soil wet weight (kg) SWWT
2) Soil dry weight (kg) SDWT
3) Soil sample volume (m^3) SVOL
4) Plant wet weight (kg) PWWT
5) Plant dry weight (kg) PDWT
6) Plant height (m) H
7) Planting density (plants m^{-2}) PD
8) Leaf Area Index per plant (m^2) LA
9) Sample size (plants/sample) S

From these measured parameters, the other parameters are calculated. They are:

1) Plant moisture content (kg m^{-3}) W

$$W = (PWWT - PDWT) * PD / (H * S) \qquad (2.1)$$

2) Leaf Area Index (m^2 m^{-2}) LAI

$$LAI = (LA * PD)/ S \qquad (2.2)$$

3) Volumetric soil moisture (kg m^{-3}) m_s

$$m_s = (SWWT - SDWT) / SVOL \qquad (2.3)$$

4) Normalized plant dry weight (kg m^{-2}) DWT

$$DWT = PDWT * PD / S \qquad (2.4)$$

5) Percentage plant water content (%) PPH20

$$PPH20 = (PWWT - PDWT) * 100\% / PWWT \qquad (2.5)$$

The ground-truth data taken in 1980 included the above parameters, and in addition, the plant parameters were measured for both plant parts and layers. The sorghum plants were divided into a top and bottom layer by chopping the plant in half. Similarly, the corn-plant samples were divided first in half, and then into thirds during the latter part of the growing season. The resulting plant dry weight and wet weight were then totaled so they would correspond to the ground-truth data taken in 1979. An example of a data set is shown in Table 2.1.

Two advantages derive from taking the plant ground-truth data in layers. First, because the data were not averaged and totaled by computer, there were errors introduced during keypunching. Therefore, having the layers available to total and compare with the keypunched total afforded an opportunity to check for keypunching errors.

The second advantage of having the layered data is the insight it lends to the relative importance of different factors in the model. Attema and Ulaby (1978) considered the water in the crop to be like water in a cloud, with the particles of water being random in size, shape, and position. The data in Table 2.2 show these assumptions to be only a first approximation. The top-layer data for corn indicates that 52.2 percent of the water contained in the layer is in the leaves. The top-layer data supports the "cloud" model by showing that the water is in the leaves which are randomly distributed. Overall, though, only 16.8

Table 2.1
Sample Ground Truth for 1980 Corn and Sorghum
Day 212, July 30,1980

Field	Layer	Leaf Dry Wt (kg)	Leaf Wet Wt (kg)	Stalk Dry Wt (kg)	Stalk Wet Wt (kg)	Fruit Dry Wt (kg)	Fruit Wet Wt (kg)	Height (m)	Leaf Area (m^2)
C-13	Top	0.075	0.279	0.064	0.251	0.000	0.000	0.784	1.016
	Mid	0.053	0.276	0.137	0.719	0.069	0.717	0.800	0.728
	Bot	0.022	0.090	0.208	1.264	0.000	0.000	0.800	0.107
	Tot	0.150	0.647	0.409	2.234	0.069	0.717	2.384	1.851
S-33	Top	0.037	0.141	0.011	0.037	0.019	0.062	0.513	0.534
	Bot	0.019	0.094	0.068	0.438	0.000	0.000	0.529	0.225
	Tot	0.057	0.235	0.079	0.475	0.019	0.062	1.042	0.750

Table 2.2
Percentage Water Content by Plant Part and by Layer
Day 212, July 30,1980

Field	Layer	Leaf % H20 Part	Leaf % H20 Layer	Stalk+Fruit % H20 Part	Stalk+Fruit % H20 Layer	Total of Layer Dry Wt (kg)	Total of Layer Wet Wt (kg)	Water Content (kg)
C-13	Top	78.8	52.2	79.7	47.8	0.139	0.530	0.391
	Mid	83.9	15.4	87.4	84.6	0.259	1.712	1.453
	Bot	80.4	6.1	85.9	93.9	0.230	1.354	1.124
	Tot	81.2	16.8	86.1	83.2	0.628	3.596	2.968
S-33	Top	73.8	60.1	69.7	39.9	0.067	0.240	0.173
	Bot	79.8	16.9	84.5	83.1	0.087	0.532	0.445
	Tot	75.7	28.8	81.8	71.2	0.154	0.772	0.617

percent of the plant's water is contained in the leaves. This means that in a dry year such as 1980, when the leaves are relatively dry, neither the LAI nor W parameters fit well in the old "cloud" model as the canopy parameter.

The 1980 ground-truth data substantiates the hypothesis that the major portion of a plant's water content is in the stalk and cob (or head) and therefore is not randomly distributed. The leaves represent most of the area intercepted by the radar, so the model must take the leaf water into consideration yet at the same time, be somewhat independent of plant water content.

Remembering that the radar averages over a wide swath of the field, and assuming that the mean plant parameters for that swath would not change as quickly as a single day's sample, the temporal data were smoothed by fitting a third- or fourth-order polynomial to them. With the exception of the soil moisture and possibly the plant moisture content W, the ground-truth parameters should be continuous in time. Certainly DWT and LAI discontinuities are more likely to be caused by sample variance or measurement uncertainty than by rapid changes in the actual mean of the parameters. Also, because the ground-truth data were not always collected on the same day as the radar data, the ground-truth data had to be smoothed and interpolated.

Smoothing the ground-truth data called for common-sense assumptions. The first assumption was that the PPH20 could not have rapid changes. Thus, if the PPH20 had a discontinuity, then either the corresponding wet- or dry-weights probably were in error. An erroneous dry weight generates a questionable DWT value, and worse yet, the plant

water content W is susceptible to errors in either of the weights. The parameter PPH20 for 1980 corn and sorghum and 1979 wheat is presented in Figure 2.1. All three sorghum and three corn fields, along with the two wheat fields, are plotted. For corn and sorghum, the parameter peaks early and slopes off as the plants dry out through the last two-thirds of the season. This parameter has less variance because the effects of sample size are reduced by dividing the water content of the sample by its wet weight. If the sample is unusually large, then both the top and bottom parts of Equation 2.5 are affected and the error is less. A careful check of all anomalies in the PPH20 yielded information on less-visible quirks in DWT and W.

The second common-sense assumption involves the parameter DWT. The normalized plant dry weight for corn as defined in Equation 2.4 is shown in Figure 2.2a. Except at the very end of the season, DWT was constrained to increase monotonically. In the latter part of the season, DWT could have decreased somewhat due to the loss of leaves and upper parts of the stalk. The quirks in DWT served as indicators that the plant sample was either relatively large or small and could be affecting the LAI and W values. In this manner, the different measured and calculated parameters were checked against each other until all the ground-truth data points were either discounted or justified.

Figures 2.2a and 2.2b show plots of the ground-truth parameters, both measured and smoothed for 1980 corn C-13. The data sets in Appendices A-E have the smoothed values only. The height parameter was very smooth and called for very little correction (Figure 2.2a). Notice the rapid, fairly linear growth of the plant. The smoothing process made

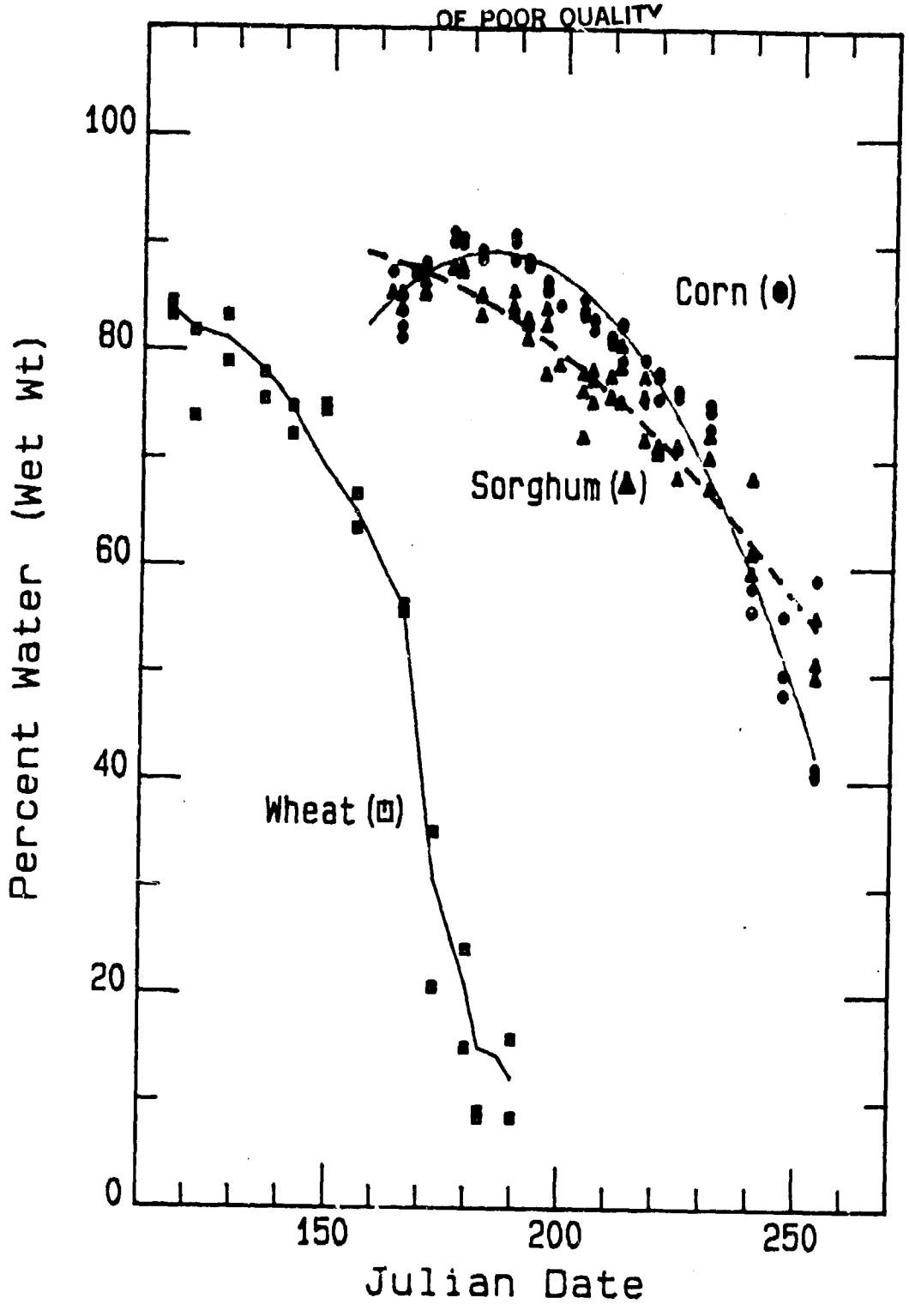


Figure 2.1. Examples of PPH20 for 1979 wheat, 1980 corn, and 1980 sorghum.

Figure 2.2. Ground truth for
1980 Corn C-13

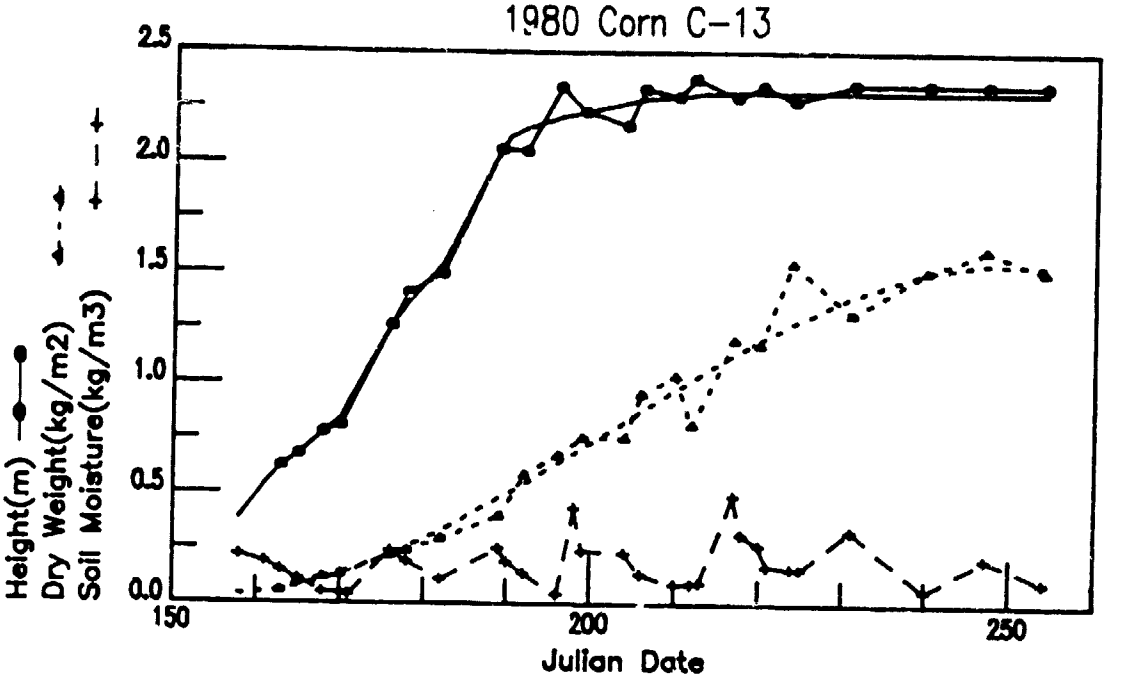


Fig. 2.2a. H, DWT, and m_s .

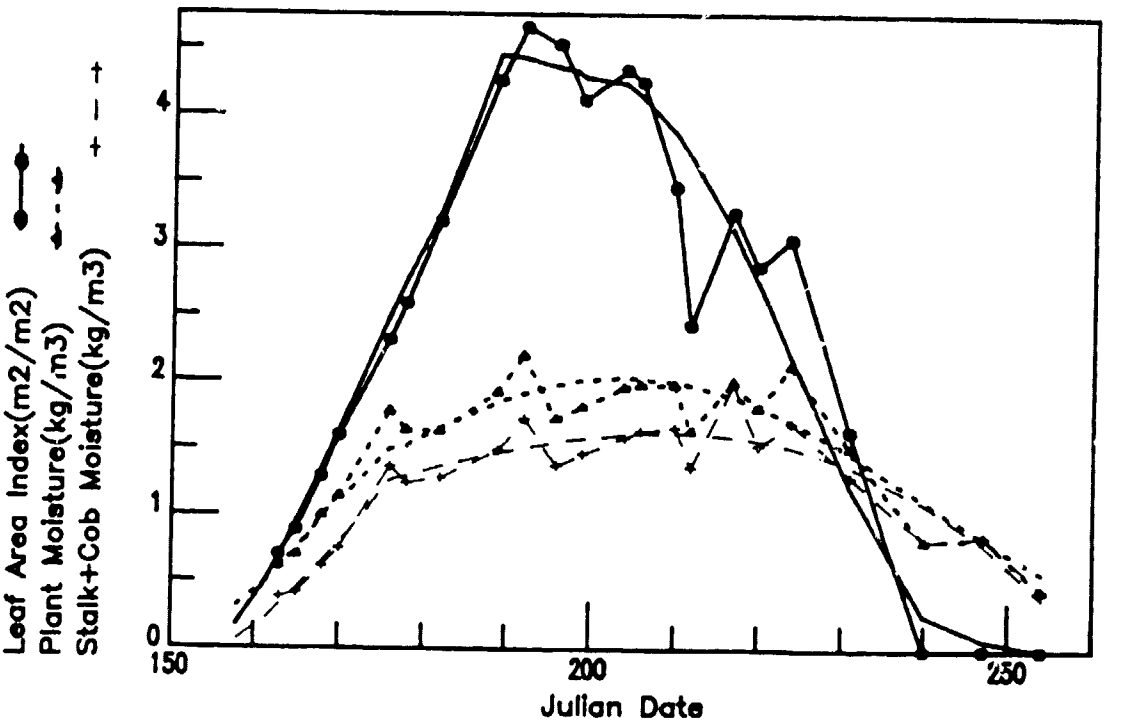


Fig. 2.2b. LAI, W, and W_{stalk} .

no attempt to include the "tasseling out" for corn; the measurement variability was large enough to mask out this event. Fortunately, the extra height from the tassles is only about 5 percent of the total height. The plant moisture content, W, unlike the plant height, appears as a rather jagged plot. Looking back at Equation 2.1, the value of W is sensitive to measurement errors in both the plant wet- and dry-weights and the plant height. As a result, the data points that were suspiciously high or low were discounted during the smoothing process. The soil moisture measurement m_s was taken every day, and except for comparing the values between fields and to the rainfall and irrigation events, it was not interpolated or smoothed. The LAI was examined for errors, first by layers and then by the total. The curve that resulted from the smoothing process was, in fact, pieced together. The rise was approximated by a parabola, the flat plateau by a line, and the fall by a third-order polynomial. Previous data taken in Colby, Kansas (Ulaby, Razani, and Dobson, 1982) exhibited a plateau region; therefore these data were smoothed to have that shape.

The ground-truth data for 1980 sorghum were handled in much the same way as the 1980 corn. The ground-truth parameters for S-33 are plotted in Figures 2.3a and 2.3b. The general trends are much the same, with the exceptions of the final height and normalized dry weight. The only real difference between the corn and sorghum was the late-season LAI and the shape of the PPH20 in Figure 2.1. Whereas the corn leaves turned brown and dried out, the sorghum leaves stayed green, so the LAI did not go to zero. The PPH20 decreased more slowly than for corn, verifying the fact that the sorghum canopy had more water during the

Figure 2.3. Ground truth for
1980 sorghum S-33

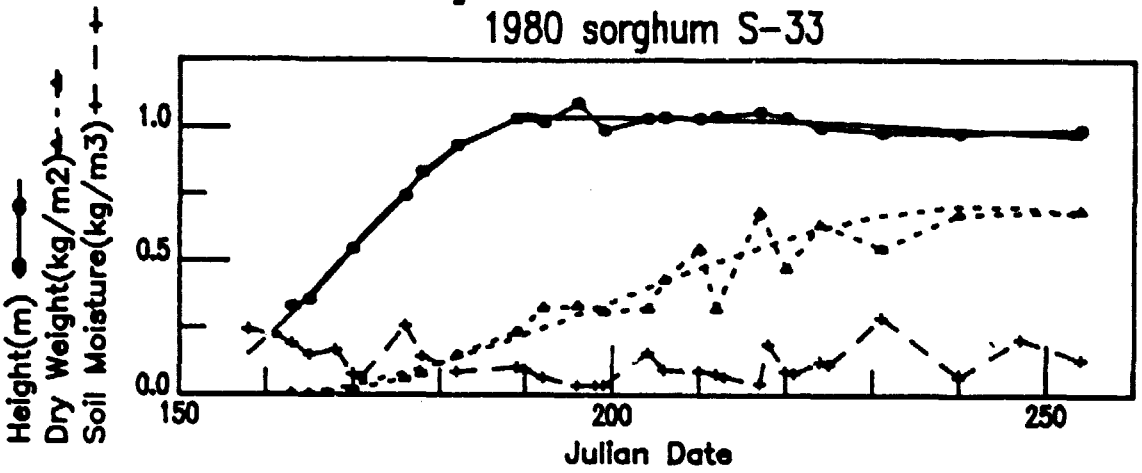


Fig. 2.3a. H, DWT, and m_s .

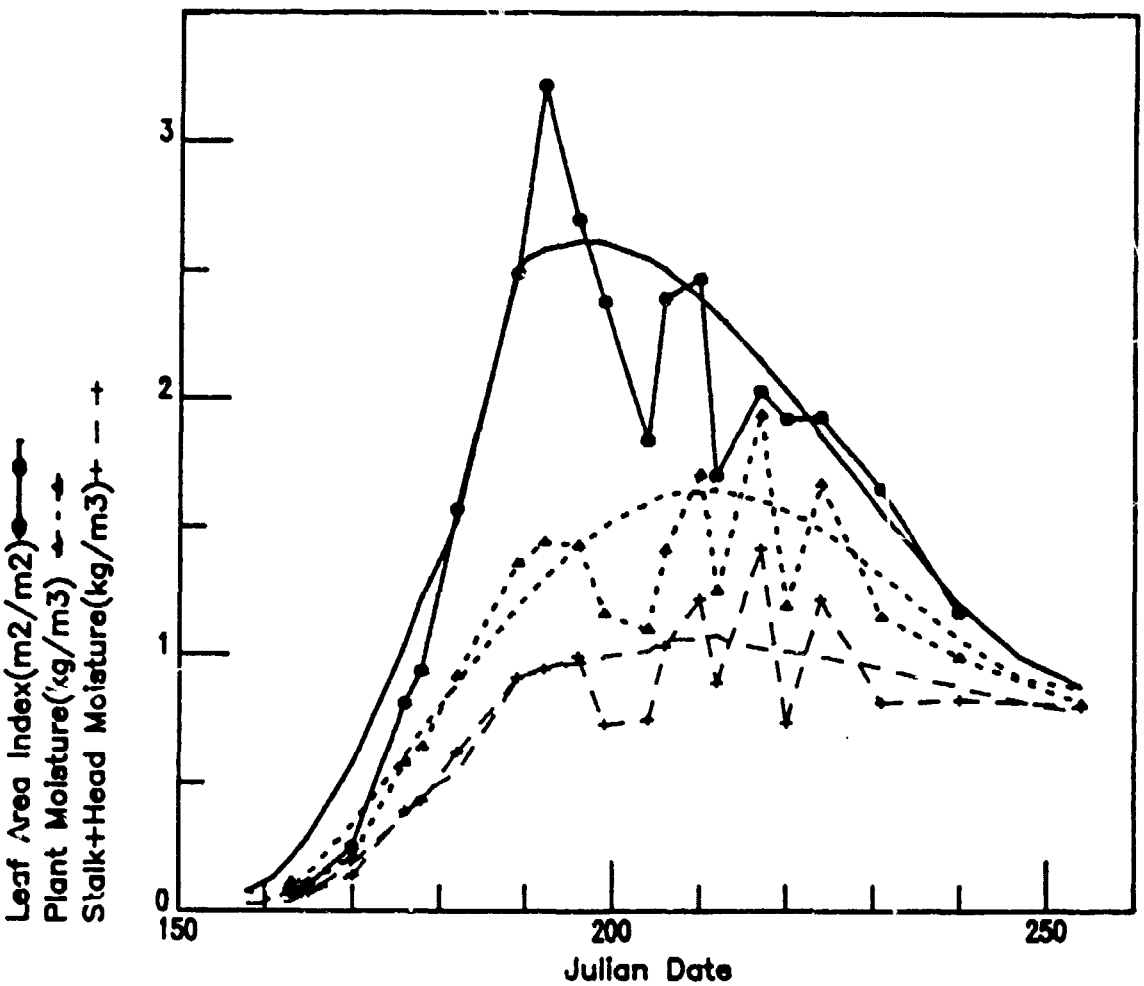


Fig. 2.3b. LAI, W, and W_{stalk} .

latter part of the season.

For the 1979 corn and sorghum, only minor changes were made in ground-truth values. The limited number of data sets on any one field made polynomial smoothing impractical. Fortunately, two fields were planted with the same planting density, so the parameters from C-11 and C-14, C-12 and C-15, etc., were compared against each other for anomalies. The fields were located within 100 meters of each other, and location differences were ignored.

The major difference between the ground-truth data taken in 1979 and that taken in 1980 is that there was much fuller growth in 1979 than in 1980. There was sufficient water in 1979 to allow the plants to grow freely, and as a result, the 1979 plants were taller, leafier, and contained more water. The corn-plant LAI did not go to zero as in 1980 because the leaves did not dry out. According to the differences in ground-truth trends, the radar data in 1980 should be lower than it was in 1979 if the return is directly proportional to the amount of water in the canopy.

The 1979 wheat crop has a much different ground-truth data than either corn or sorghum. The ground-truth data from field W-41 are presented in Figures 2.4a and 2.4b. The LAI for wheat is much higher and peaks much earlier than for the other two. The dry weights are lower at the beginning of the season and are similar when the ends of the seasons are compared. The plant moisture content is also different as shown by the existence of a second small peak towards the end of the season. This smaller rise in W is probably due to the growth and filling of the wheat head. Similarly, the increase in DWT in the middle

Figure 2.4. Ground truth for
1979 Wheat W-41.

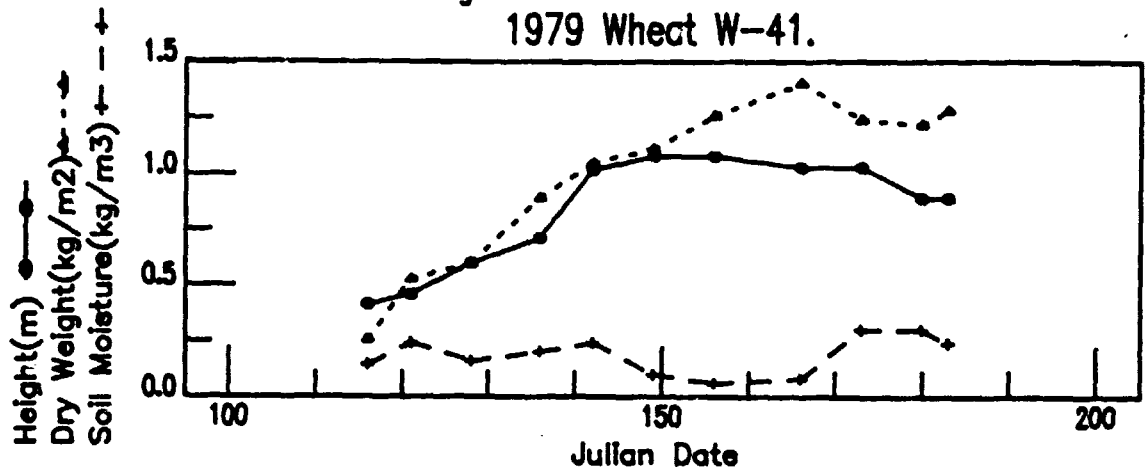


Fig. 2.4a. H, DWT, and m_s .

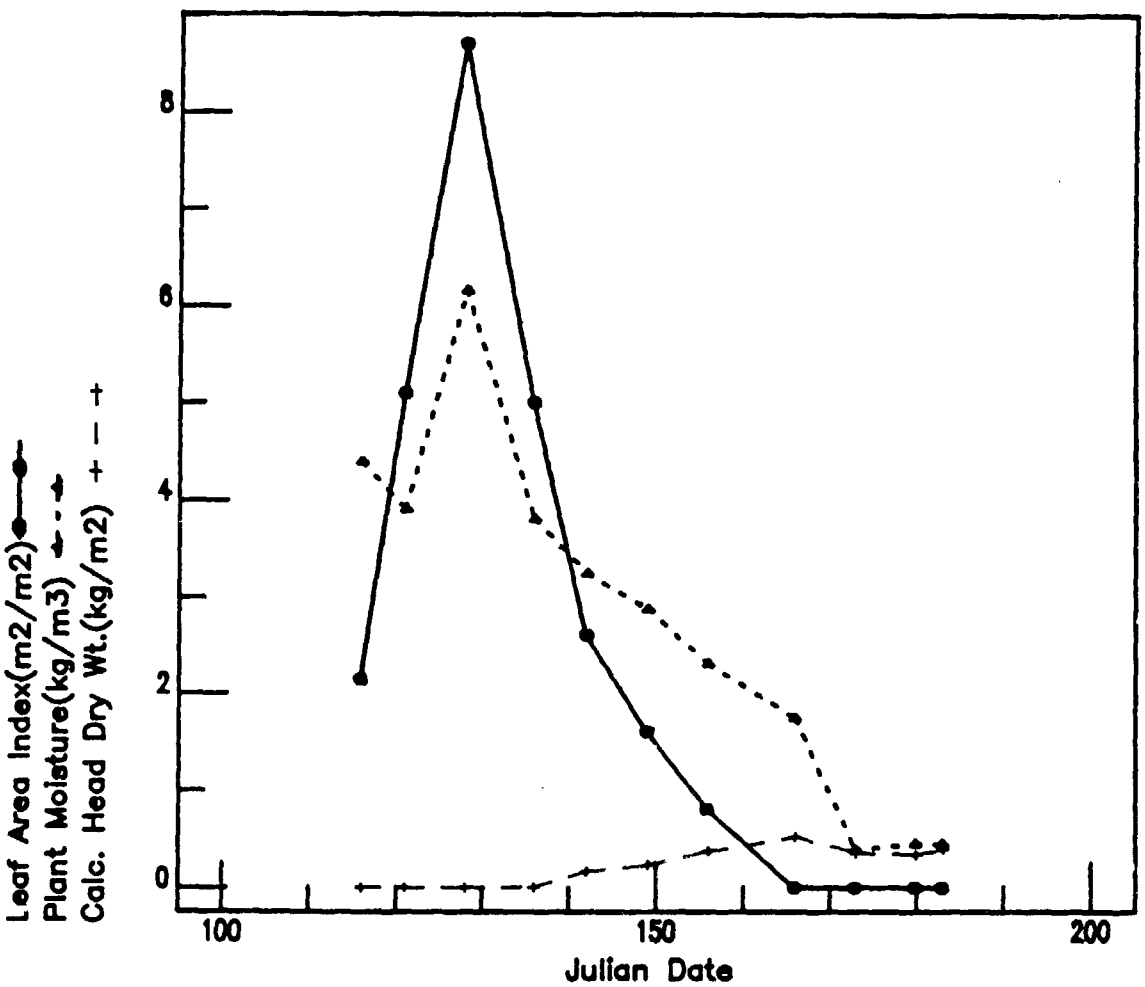


Fig. 2.4b. LAI, DWT, and DWT_{head} .

and at the end of the season is due to the wheat's head growth. The head dry weight was not measured in 1979, but an approximation was calculated by finding the increase in total plant dry weight after the plant had matured. The last data taken before heading occurred were acquired on Day 136. The head dry weight was calculated by subtracting the dry weight on Day 136 from the dry weight measured for the succeeding days. This calculated parameter will be discussed in more detail in the model section.

2.2. Radar Data

The 1979 radar data were taken at four frequencies, two polarizations, and three angles of incidence. The frequencies measured were 8.6, 13.0, 17.0, and 35.6 GHz. Frequencies below 8.6 GHz respond too well to the soil moisture changes and therefore would not be as sensitive to crop parameter changes. Frequencies above 35.6 GHz have very short wavelengths and thus only a limited penetration into the crop. Therefore, the higher frequencies would not respond as well to the overall plant characteristics.

Although the measurements were made for HH, VV, and HV polarization configurations, the HV data will not be presented. They were not sufficiently higher than the system noise floor to be considered reliable.

The data were measured at incidence angles of 30, 50, and 70 degrees from normal. The range of angles was chosen to give the best response from the canopy. Low angles of incidence (0-25 degrees) would penetrate through the canopy and would respond to the soil moisture events. High angles of incidence (70-90) would not penetrate very

deeply and would respond only to the top part of the canopy. Only the 50 degree data will be presented so that the extra variable of incidence angle will not hinder the comparison between 1979 and 1980.

The 1979 radar data, while including a larger number of angles and fields, did not have enough sample points from the growing season for any one field and angle to accurately model the radar interaction. With this shortcoming in mind, the 1980 experiment was designed to be more concentrated and to have enough temporal samples to allow the testing of different models. The 1980 data have the same frequencies and polarizations as the 1979 data. The single incidence angle, 50 degrees, was chosen to try to balance the above sensitivity considerations.

In 1979, each field was spatially sampled 15 times and then averaged. This amount of spatial uncertainty, along with frequency averaging over the footprint, results in approximately 1.0 dB of uncertainty. In order to reduce the uncertainty, the number of spatial samples in 1980 was increased to 25 per data set. Again combined with frequency averaging, the uncertainty due to fading is less than 0.5 dB (Stiles, Brunfeldt, and Ulaby, 1979).

In 1980, one additional effort was made to more accurately calibrate the data. As opposed to 1979, external lens reflector calibration was performed daily. This daily calibration was then used to correct the data set. However, no lens calibration was performed during five of the days, and therefore season averages were used in those cases.

3.0 MODEL DEVELOPMENT

3.1 Corn and Sorghum

An accurate model of the radar backscatter from corn and sorghum must include effects from both the canopy and the underlying soil. Before the plants grow and cover the field, soil characteristics will be the driving influence in determining the radar backscatter. The first part of this model in terms of its temporal importance is σ°_{soil}, the term due to the soil moisture. Clearly σ°_{soil} should be dependent on the water content of the soil. A change in the amount of water present will change the dielectric constant of the soil and therefore strongly influence the backscatter. In this model, m_s, the volumetric soil moisture content, will be used as the variable in σ°_{soil}. Ulaby, Bradley, and Dobson (1979) have shown that the radar backscatter from soil has an exponential response to soil moisture. For the sake of simplicity, the response will be modeled as having a linear dependence on m_s.

As the plants develop and begin to cover the ground, the σ°_{soil} contribution should diminish because the radar must penetrate through the plants before reaching the soil. This model includes attenuation terms from the leaves and stalks in the canopy above the soil. The attenuation due to a small layer of leaves is assumed to be dependent on the number of leaves in the layer. The total attenuation, E_1, due to the leaves results from the integration of all the attenuation from the layers of leaves. The attenuation constant due to one small layer of

leaves is:

$$\alpha_{leaf} = \frac{E' \cdot LAI}{H} \tag{3.1}$$

where E' is a constant, LAI is the leaf area index ($m^2\ m^{-2}$) of the crop, and H is the height of the crop in meters. The attenuation of the leafy part of the canopy, after integrating over the thickness of the canopy is:

$$E_1 = e^{\int_0^{z_0} \alpha\, dz} = e^{-\frac{E' \cdot LAI}{H} z_0} \tag{3.2}$$

where z_0 is the thickness of the canopy in meters. Another attenuation term must be included resulting from the effect of the large amount of water present in the stalks. This attenuation should be proportional to the stalk water content, W_{stalk}. Based on the ground-truth data taken in 1980, the majority of the water in the plant is in the stalk. Therefore, the plant water content will be used as the input to this part of the model. Finding the attenuation for one small layer of stalks:

$$\alpha_{stalk} \propto W_{stalk} \sim D' \cdot W \tag{3.3}$$

where D' is a constant and W is the total plant water content (kg/m^3). The total attenuation from the stalk, E_2, after integrating over the

whole canopy becomes:

$$E_2 = e^{-\int_0^{z_0} D' \cdot W \, dz} = e^{-D' \cdot W \cdot Z_0} \tag{3.4}$$

After substituting $H/\cos\theta$ for z_0, noting that the thickness of the canopy layer is equal to the height of the canopy divided by the cosine of the incidence angle, the equation for the soil contribution is:

$$\sigma^o_{soil} \alpha m_s \cdot e^{-\frac{E' \cdot LAI}{\cos\theta}} \cdot e^{-\frac{D' \cdot W \cdot H}{\cos\theta}} \tag{3.5}$$

One final step leads to the final form of σ^o_{soil}. Since the incidence angle is always 50 degrees, combining the constants and $\cos\theta$ together yields:

$$\sigma^o_{soil} \alpha m_s \cdot E_1 \cdot E_2 = C_{soil} \cdot m_s \cdot e^{-E \cdot LAI} \cdot e^{-D \cdot W \cdot H} \tag{3.6}$$

The second term of importance in modeling the radar interaction is contributed by the leaves of the crop. Ground-truth data indicates that while only a small portion of a plant's water content is in its leaves, the leaves themselves are as much as 80 percent water. This high percentage of water, coupled with the broad areal coverage of the leaves, requires that the leaves be included in the model.

In the past, the modeled response from the crop canopy has been simplified to the point that it has not taken into consideration the geometry of the canopy. The leaves and stalks were not considered separately, and the response from the canopy was modeled as if it were

a cloud. The scatterers in the vegetation were approximated as being randomly distributed drops of water of equal size. With these constraints, Attema and Ulaby (1978) have modeled the contribution from the vegetation in the following form:

$$\sigma^{o}_{veg} = C\,(1 - e^{-\frac{D''\cdot W\cdot H}{\cos\theta}})\cos\theta \qquad (3.7)$$

where C and D'' are constants, and W, H, and θ are defined as before.

Attema and Ulaby arrive at the above equation by first defining the reflectivity and attenuation due to one scattering particle of the crop "cloud." Then, integrating over the entire illuminated canopy volume, they arrive at the total contribution from the vegetation. They define the radar cross section of a particle as σ, so the radar cross section per unit volume, η, becomes $\eta = N\,\sigma$, where N is the number of scatterers per unit volume. Similarly, they define the total attenuation cross section for one scatterer to be Q. This results in the power attenuation coefficient per unit length, α, to be $\alpha = N\,Q$.

From this starting point, they proceed to define the geometry of the problem. After asuming the radar illuminates a cylinder of crop canopy, the incident power, P_i on the canopy and the average backscattered power, P_r, from the canopy are described by:

$$P_i = S \cdot A_{ill} \cdot \cos\theta \qquad (3.8)$$

$$\bar{P}_r = S \cdot A_{ill} \cdot \cos\theta \int_0^{z_0} N\cdot\sigma\cdot e^{-\int_{z'}^{z_0} 2\alpha\cdot z'\cdot dz'}\, dz \qquad (3.9)$$

where S is the power density of the radar waves illuminating a surface area A_{ill} and θ is the incidence angle from nadir. Solving for the contribution from the vegetation, σ^o_{veg}:

$$\sigma^o_{veg} = \frac{\bar{P}_r}{S \cdot A_{ill}}$$

$$= \cos\theta \int_0^{z_0} N \cdot \sigma \cdot e^{-\int_{z'}^{z_0} 2\alpha \cdot dz'} \, dz \qquad (3.10)$$

where z_o is the distance traveled through the canopy as before. Notice that the attenuation part of this equation has different limits for integration because a given layer of canopy is attenuated only by the layers of canopy above it. Again noting that $z_o = H/\cos\theta$ and substituting for α, the contribution from the vegetation is:

$$\sigma^o_{veg} = \cos\theta \cdot \frac{\sigma}{2Q} \left(1 - e^{-\frac{2N \cdot Q \cdot H}{\cos\theta}}\right) \qquad (3.11)$$

The ratio of $\sigma/2Q$ depends on the individual scatterer, and therefore can be replaced by a single parameter, C. The number of scatterers per unit volume, N, should be proportional to the volumetric water content of the canopy, W. Finally, assuming Q to be constant for all the scatterers and replacing 2Q in the exponent with a single constant D'', the equation simplifies to:

$$\sigma^o_{veg} = C \left(1 - e^{-\frac{D'' \cdot W \cdot H}{\cos\theta}}\right) \cos\theta \qquad (3.12)$$

Instead of assuming that the canopy has randomly distributed, equal-sized particles, the new model takes advantage of the geometry of the plant in defining the contribution from the vegetation. The scattering due to the leaves is taken to be a separate contribution to the predicted backscatter from that of the scattering due to the stalk. The idea of modeling the leaves as a cloud of water particles has merit but instead of using the plant water content, LAI could be used as the input. This variable more closely tracks the number of leaf scatterers in the canopy. For a thin layer of leaves, the backscatter and attenuation can be modeled by:

$$d\sigma^{\circ}_{leaf} \propto \frac{LAI}{H} \cdot e^{-\int_{z'}^{z_0} \alpha \, dz'} \cos\theta \qquad (3.13)$$

where the first part is the backscatter from the layer of interest, and the exponential term is the attenuation through the layers above the layer of interest. This equation assumes that the backscatter from the leaves is due to the presence of randomly distributed water drops as in the model by Attema and Ulaby. As in the soil term, the attenuation constant due to the leaves is:

$$\alpha = \frac{E' \cdot LAI}{H}$$

For the total contribution from the canopy, integrating over the layers of the canopy and including the constant A_{leaf} for the proportionality:

$$\sigma^{\circ}_{leaf} = \int_0^{z_0} \cos\theta \cdot A'_{leaf} \cdot \frac{LAI}{H} \cdot e^{-\int_{z'}^{z_0} \frac{E \cdot LAI}{H} \, dz'} \, dz \qquad (3.14)$$

Removing the z-independent variables from inside the first integral and solving the integrals yields:

$$\sigma^{\circ}_{leaf} = A'_{leaf} \cdot \cos\theta \left(1 - e^{-\frac{E' \cdot LAI}{H} Z_0}\right) \tag{3.15}$$

The final form of the contribution from the leaves, after substituting for z_o and combining the constants and $\cos\theta$ together is:

$$\sigma^{\circ}_{leaf} = A_{leaf} \left(1 - e^{-E \cdot LAI}\right) \tag{3.16}$$

The final term of this three-part model considers the importance of the stalk. Even though the leaves cover the greatest area, the large amount of water present in the stalk requires the model to include a contribution from the stalk. Two relationships help define the σ°_{stalk} term. First, the stalk term should be proportional to W_{stalk}, the stalk water content. Secondly, the leaves cover the stalks and therefore attenuate the stalk contribution. If one layer of stalks has backscattering of the form:

$$d\sigma^{\circ}_{stalk} \alpha W_{stalk} \cdot e^{-\int_{z'}^{z_0} \alpha \, dz' \cos\theta} \tag{3.17}$$

then the total backscatter from the stalk, by integrating over the

layers of the crop is:

$$\sigma^{o}_{stalk} \alpha \int_{0}^{z_0} \cos\theta \cdot W_{stalk} \cdot e^{-\int_{z'}^{z_0} \alpha \, dz'} \tag{3.18}$$

Substituting for z_o, α, approximating W_{stalk} with W, and including a constant of proportionality B_{stalk}, the equation becomes:

$$\sigma^{o}_{stalk} = \frac{B_{stalk} \cdot W \cdot H}{E \cdot LAI} \left(1 - e^{-E \cdot LAI}\right) \tag{3.19}$$

Notice the attenuation exponential has been derived with the assumption that the stalks and leaves are interspersed and therefore the stalk is attenuated by only the leaves above it. The model, with all the terms, has the form:

$$\begin{aligned} \sigma^{o}_{pred} &= \sigma^{o}_{leaf} + \sigma^{o}_{stalk} + \sigma^{o}_{soil} \\ &= A_{leaf} \left(1 - e^{-E \cdot LAI}\right) \\ &+ \frac{B_{stalk} \cdot W \cdot H}{E \cdot LAI} \left(1 - e^{-E \cdot LAI}\right) \\ &+ C_{soil} \cdot m_s \cdot e^{-D \cdot W \cdot H} \, e^{E \cdot LAI} \end{aligned} \tag{3.20}$$

No attenuation from the stalks was included in the first two terms. The assumption has been made that the stalks do not significantly block the leaves or each other due to the row spacings and planting densities. This assumption will be examined in the results.

3.2 Wheat Model

Wheat has a different geometry than either corn or sorghum and requires modifications of the model introduced in the previous section. First, the wheat stalks are much smaller and contain a smaller portion of the total plant water. Secondly, the size, location, and relative water content of the head or fruit makes it important. The first and most significant change occurs in the second term of Equation 3.20. Because the head of the wheat plant is above the leaves, the leaves should not attenuate the response from the head. Another change is necessary in this term. The physical parameter W is not representative of the increase in head moisture. During the time that the head is growing and filling with water, the overall plant moisture is decreasing due to the drying of the leaves an stalks. The best parameter for following the growth and maturation of the head would be the head's water content in kilograms per square meter:

$$W_{head} = \frac{(HWWT - HDWT) \quad SS}{PD} \tag{3.21}$$

where:

HWWT = Head wet weight in kg/sample

HDWT = Head dry weight in kg/sample

SS = Number of plants per sample

PD = Planting density in plants/m2

Since this parameter was not measured in 1979, a substitute must be found. If the plant is assumed to be fully developed before heading takes place, then the dry weight due to the leaves and stalks should be constant for the period during and after heading. Any change in dry weight after the onset of heading will be directly related to the development of the head. Using this reasoning, the parameter DWT_{head} is calculated from the total plant dry weight as follows:

$$DWT_{head}(t) = 0 \qquad \text{if } t < to, \text{ the heading date}$$
$$DWT_{head}(t) = DWT(t) - DWT(to) \qquad \text{if } t > to \qquad (3.22)$$

The resulting parameter is plotted in Figure 2.4b with to = 136 (May 16th, 1979). This date is the first that has full plant height and observed heading.

Attempts to generate a parameter based on the plant-moisture content that would correspond to the head-moisture content resulted in a negative parameter with poor general shape and correlation. The data were tested for correlation to both W_{head} and DWT_{head} over the last part of the growing season (Days 150-183), and there was better correlation with DWT_{head}. Combining this new variable with the change due to the absence of leaf coverage, the second term of the model becomes:

$$\sigma^{o}_{head} = B_{head} \cdot DWT_{head} \qquad (3.23)$$

Minor changes in the first and third terms must also be made. In the first term, because the wheat leaves are below the head, there is

the possibility that the head attenuates the return from the leaves. If the attenuation constant is assumed to be proportional to DWT_{head}, the first term must have the form:

$$\sigma^{\circ}_{leaf} = A_{leaf} \cdot LAI \cdot (1 - e^{-E\ LAI}) \cdot e^{-D\ DWT} \tag{3.24}$$

The soil term will also suffer from this attenuation but may no longer suffer from attenuation in the stalks because of the decreased importance of the stalks. The results of these considerations are:

$$\sigma^{\circ}_{soil} = C_{soil} \cdot m_s \cdot e^{-D \cdot DWT} \cdot e^{-E \cdot LAI} \tag{3.25}$$

The model was tested and did not respond strongly enough to LAI in the first half of the growing season. If the scatterers of the canopy are no longer assumed to be equal in size, then the backscatter portion of Equation 3.16 is no longer proportional to LAI, but to LAI squared. This change included with the above changes results in the final form of the model for wheat:

$$\begin{aligned} \sigma^{\circ}_{pred} &= \sigma^{\circ}_{leaf} + \sigma^{\circ}_{head} + \sigma^{\circ}_{soil} \\ &= A_{leaf} \cdot LAI\ (1 - e^{-E \cdot LAI})\ e^{-D \cdot DWT} \\ &\quad + B_{head} \cdot DWT_{head} \\ &\quad + C_{soil} \cdot m_s \cdot e^{-D \cdot DWT}\ e^{E \cdot LAI} \end{aligned} \tag{3.26}$$

4.0 COMPARISON OF MODEL AND OBSERVED DATA

4.1 1979 Wheat

The coefficients for the model were found by using a non-linear regression program (Dixon and Brown, 1977) to minimize the least-squared error between the predicted and observed values. The number of data points for any one field, frequency, and polarization combination was too small to have the constants converge. It was necessary to analyze simultaneously all data having the same polarization. The coefficients were constrained to have a linear dependence on wavelength in order to limit the range of values for the coefficients and to force the model to show frequency trends.

The best-fit coefficients and the resulting correlation between the observed and predicted values are presented in Table 4.1. The data for Field W-41, along with the predicted values and its components are plotted in Figures 4.1, a-d. The correlation coefficients range between a high of 0.98 and a low of 0.78. In general, each field's data correlates well with the predicted values, with Field W-41 being slightly better with the exception of 8.6 GHz VV. There is no significant planting-density difference between fields: 1661 plants per square meter for W-41 versus 1671 plants per square meter for W-42. The LAI difference between the fields is sizable, with W-42 having a peak LAI 30 percent lower than W-41. The observed radar data responds to the higher LAI in W-41; the values for σ°_{obs} during the LAI-influenced period are higher for W-41 than for W-42. The model tracks this difference between

Table 4. 1
Manhattan Agricultural Experiment Model Coefficients
and Correlation between Predicted and Observed σ^o
with Linear Wavelength Constraint for
1979 Wheat Fields W-41 - W-42

1979 WHEAT VV
FIELDS W-41 - W-42

FREQ(GHz)	A_{leaf}	B_{head}	C_{soil}	D	E
8.6	0.0202	0.1062	1.2897	3.9798	1.1704
13.0	0.0267	0.0650	0.8050	2.7777	0.7480
17.0	0.0297	0.0460	0.5813	2.2233	0.5530
35.6	0.0348	0.0138	0.2023	1.2837	0.2228

FREQ(GHz)	ρ_{41}	ρ_{42}
8.6	0.776	0.844
13.0	0.973	0.847
17.0	0.949	0.958
35.6	0.978	0.879

1979 WHEAT HH
FIELDS W-41 - W-42

FREQ(GHz)	A_{leaf}	B_{head}	C_{soil}	D	E
8.6	0.0126	0.0858	0.9868	3.3902	0.7116
13.0	0.0224	0.0582	0.6167	2.0508	0.4699
17.0	0.0269	0.0456	0.4465	1.4348	0.3590
35.6	0.0345	0.0241	0.1574	0.3888	0.1701

FREQ(GHz)	ρ_{41}	ρ_{42}
8.6	0.848	0.899
13.0	0.944	0.801
17.0	0.956	0.857
35.6	0.984	0.870

Figure 4.1a. Comparison of predicted and observed Sigma0 vs date for 8.6 GHz, VV, 1979 wheat W-41.

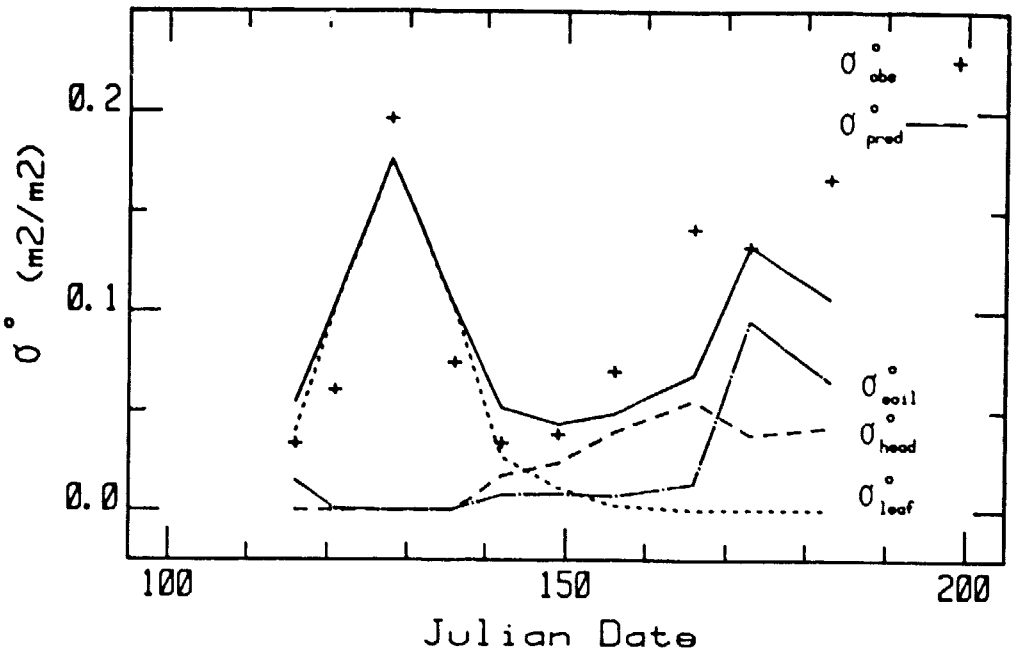


Figure 4.1b. Comparison of predicted and observed Sigma0 vs date for 13.0 GHz, VV, 1979 wheat W-41.

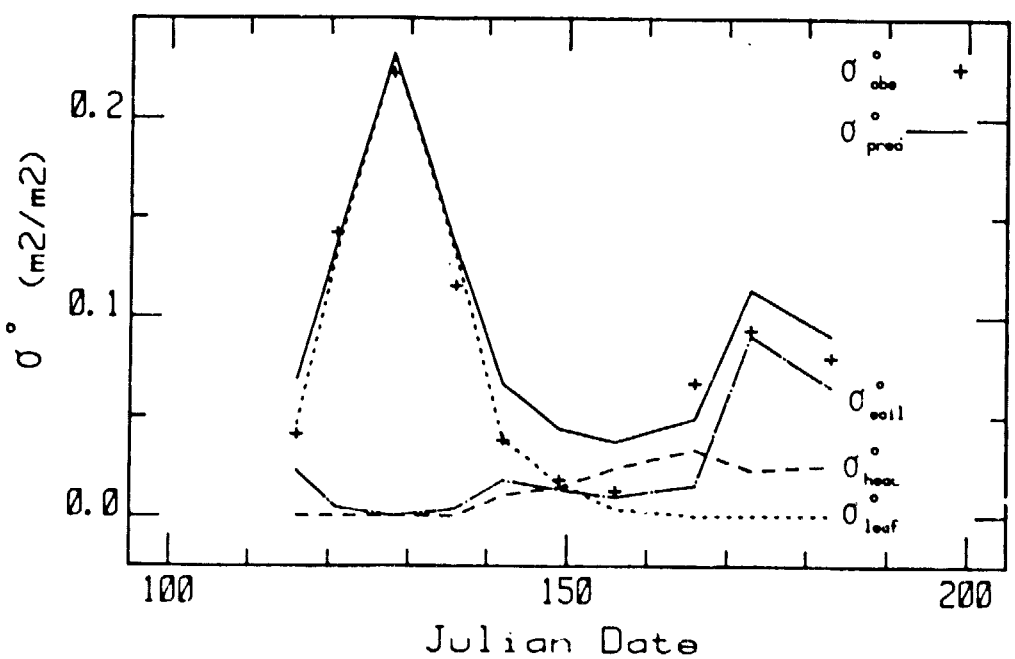


Figure 4.1c. Comparison of predicted and observed SigmaØ vs date for 17.Ø GHz, VV, 1979 wheat W-41.

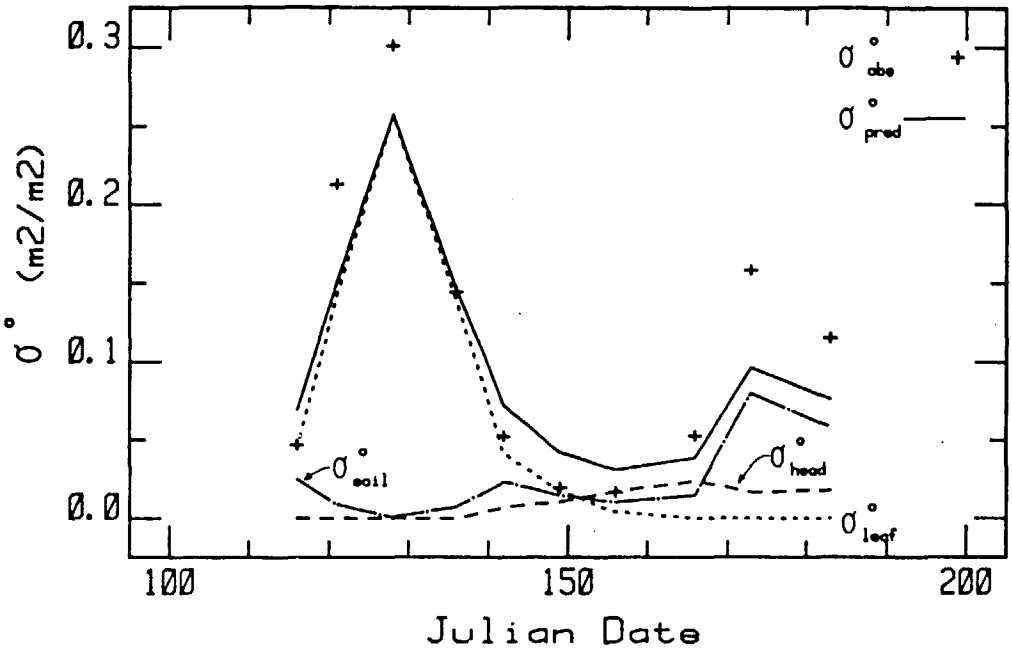
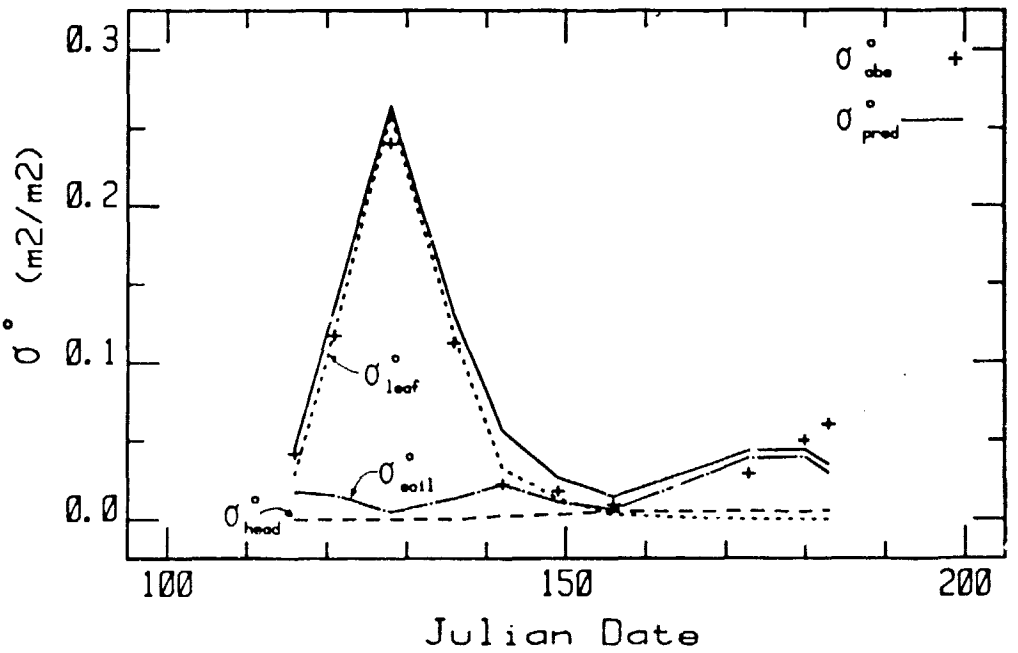


Figure 4.1d. Comparison of predicted and observed SigmaØ vs date for 35.6 GHz, VV, 1979 wheat W-41.



fields quite accurately. The yield difference for the two fields is somewhat significant, but the model does not respond to this difference. The W-41 field has a yield of 4020 kilograms per hectare, while the W-42 yield is 3639 kilograms per hectare. Without the real values for WWT_{head} and more varied fields, the lack of response cannot be considered significant.

The higher frequencies' data correlate better than those at 8.6 GHz. The 8.6-GHz data should be the most dependent on soil moisture because among the frequencies under consideration, the penetration through the canopy is best at 8.6 GHz. The σ^{o}_{soil} term in the model has been simplified by taking a linear response to soil moisture and leaving out any roughness dependence. These simplifications may be the cause of the lower correlation with 8.6 GHz.

Examining the graphs of the component parts of the predicted backscatter (Fig. 4.1, a-d) indicates that the leaf term dominates the early return for all frequencies. This dependence was expected and the model predicts the values quite well. During the last half of the season (after the leaves have turned brown) the backscatter is dependent on a combination of σ^{o}_{soil} and σ^{o}_{head}. The σ^{o}_{head} is not as important at higher frequencies.

The frequency trends in the leaf and soil coefficients substantiate the model; the leaf coefficients become larger with increasing frequency, while the C_{soil} values decrease. These trends are reasonable because higher frequencies would have there would be more wavelengths of canopy to penetrate, therefore there would be more contribution from the leaves and less from the underlying soil. The coefficients B_{head}

and D do not exhibit the expected frequency trends. Both of these coefficients decrease with frequency. The wheat head is only 5- to 10-cm long when fully grown and it is above the rest of the canopy. This implies that the head should have the greatest effect at the highest frequency. Part of the difference in the trend might be due to errors in the values for the head water content W_{head} and the calulated DWT_{head}, the variable used for the head water content.

The last parameter to consider is the leaf-attenuation coefficient, E. This parameter unexpectedly decreases with frequency. Higher frequencies have more wavelengths of canopy to penetrate, resulting in more attenuation. Only if the dielectric constant were to change such that the attenuation for a given thickness of canopy was smaller for higher frequency could the canopy have less attenuation for higher frequency. Unfortunately, at least for clouds, the attenuation per kilometer for a given water distribution increases with frequency (Ulaby, Moore and Fung, 1981). To explain this possible flaw in the model, the first half of the season was examined. Because the rise to the peak on Day 128 is rapid, the regression program has determined the parameters such that the higher frequencies have higher-than-linear dependence on LAI. The only way for the regression to have a larger-than-linear dependence is for E to be small. The need to follow the sharp rise in Days 110-130 has overpowered the normal frequency trend of E. More data points in this period or a higher-order dependence on LAI in the leaf term would help to resolve the conflict. One positive result is that the combination of E and C_{soil} does lead to less contribution from the soil as frequency increases.

Comparing the coefficients for the two polarizations indicates at lower frequencies, there is generally more return when using VV polarization. The coefficients for the 8.6 GHz, VV, are all larger than 8.6 GHz, HH. As the frequency is increased, the differences due to polarization of the coefficients A, B, and C diminish. The attenuation coefficients still exhibit sizable differences with polarization. The head attenuation coefficient D is higher for VV polarization, which is reasonable. More attenuation with VV is expected considering that the heads are more vertical than horizontal. Similarly, the leaf attenuation coefficient E has higher values for VV.

In general, for wheat, the model fits extremely well. However, the model may not fit as well as this data implies because the number of data points is fairly small and one of the ground-truth inputs, DWT_{head}, was estimated. More data points are needed to reduce the uncertainty in the estimate of the coefficients, but as a whole the model is quite applicable.

4.2 1979 Sorghum

The 1979 sorghum data were analyzed with all fields, one frequency and one polarization at a time. The number of data points was large enough to allow the analysis of each frequency separately, instead of having to constrain the coefficients to linear wavelength dependence as in the case of the wheat data. As a result of this method of analysis, the frequency trends are not as apparent as with wheat. The coefficients and correlations are listed in Table 4.2.

Table 4.2
Manhattan Agricultural Experiment Model Coefficients
and Correlation between Predicted and Observed σ^o
1979 Sorghum Fields S-31 - S-36

VV Polarization

FREQ(GHz)	A_{leaf}	B_{stalk}	C_{soil}	D	E
8.6	0.1773	0.0174	0.5575	1.0304	0.7339
13.0	0.1502	0.0413	0.7500	1.5460	0.7611
17.0	0.2298	0.0067	0.7500	0.3969	0.4000
35.6	0.1859	0.0295	0.7500	1.5810	0.4000

FREQ(GHz)	ρ_{31}	ρ_{32}	ρ_{33}	ρ_{34}	ρ_{35}	ρ_{36}
8.6	0.885	0.838	0.819	0.927	0.764	0.844
13.0	0.859	0.951	0.858	0.849	0.820	0.751
17.0	0.833	0.946	0.883	0.869	0.875	0.804
35.6	0.944	0.789	0.924	0.808	0.946	0.922

HH Polarization

FREQ(GHz)	A_{leaf}	B_{stalk}	C_{soil}	D	E
8.6	0.1413	0.0325	0.7500	1.1640	0.5055
13.0	0.1507	0.0102	0.4177	1.3710	0.7990
17.0	0.1989	0.0077	0.7500	0.4624	0.4000
35.6	0.1513	0.0090	0.7500	1.1630	0.4450

FREQ(GHz)	ρ_{31}	ρ_{32}	ρ_{33}	ρ_{34}	ρ_{35}	ρ_{36}
8.6	0.946	0.921	0.896	0.961	0.975	0.914
13.0	0.906	0.805	0.900	0.910	0.803	0.822
17.0	0.850	0.944	0.910	0.897	0.970	0.873
35.6	0.907	0.600	0.783	0.688	0.801	0.792

In general, A_{leaf} increases for both polarizations with increasing frequency. The increase in A_{leaf} is consistent with the model; as with wheat, there should be a greater contribution from the leaves with increasing frequency. The data were also analyzed using the wavelength constraints as with wheat, and the increase-with-increasing frequency trend was very definite. Of the five constants, A_{leaf} had the smallest amount of uncertainty and the most definite frequency trend.

The stalk-moisture coefficient B_{stalk}, decreases with frequency. The VV data points do not show this trend as well as the HH data. Due to the physiology of the plant, more of the stalk water is found in the lower portion of the stalk. The stalks taper from their thickest point, at or near ground level, to their thinnest diameter at the top of the plant. This geometry implies that a low frequency should receive more contribution from the lower, thicker part of the stalk which has the larger water content. The B_{stalk} frequency trend, while not as substantial as the trend in A_{leaf}, does support the assumptions of the model.

Because of the relatively small number of data points acquired while the crop was small, the value for the soil contribution is not well-established. The soil coefficient C_{soil} shows very little frequency dependence. Examination of the data in Appendix B reveals that the contribution of the soil is small except in the first part of the season for all frequencies. The lack of data during the period when σ^{o}_{soil} is important makes it impossible to grade the model's frequency performance with respect to the soil coefficient.

The stalk attenuation constant D does not display a clear frequency trend but is significant at all frequencies. Except at 17.0 GHz, the stalk attenuation is fairly constant with a value of 1.0-1.6 nepers m^2kg^{-1}. The 17.0-GHz data exhibits a very low stalk attenuation, and although the regression analysis did show some advantage to raising D, the values for D in Table 4.2 and Appendix B did have the lowest mean-square error residual. Again, more data points are needed to test this anomaly.

The final coefficient, E, shows a tendency toward lower attenuation with higher frequency. The trend is not as pronounced as it is in wheat, and the attenuation due to the leaves, even at the higher frequencies, does cause sizable attenuation of the soil contribution. Modeling the leaf attenuation upon the leaves, stalks, and soil contributions with only one parameter probably is causing a compromise in the determination of that parameter. It is unlikely that the attenuation produced by the layers of leaves above on the return of the lower leaves is exactly the same as the attenuation on the stalks' backscatter since the geometry of these two plant parts is different. A more accurate but more complicated model would include separate leaf attenuation terms for the soil, leaf, and stalk contributions.

The different polarization coefficients exhibit trends similar to those of the wheat coefficients. The A_{leaf} and B_{stalk} coefficients are higher for VV than it is for HH. The C_{soil} values are almost the same for the two polarizations, and the average stalk attenuation for VV is higher than for HH. The leaf-attenuation average is almost identical for HH and VV. Remembering the values for wheat with $E_{VV} > E_{HH}$ for all

frequencies, the difference between crops can be understood when the relative sizes of the leaves are considered. Wheat has long, thin, and mostly vertical leaves while sorghum has larger, wider leaves that curve through quite a wide range of angles. The width of the wheat leaves is about one centimeter, which may be too small to cause much attenuation in HH. The width of the sorghum leaves, however, is as much as 15-cm wide, depending on the stage of growth. This width could be large enough to cause attenuation with both HH and VV polarizations and may explain the fact that E_{HH} is higher for sorghum than for wheat.

The between-field differences for the six sorghum fields are small. The densest fields (S-31 and S-34) have higher LAI and W values, and also higher σ°_{obs}-to-LAI and σ°_{obs}-to-W correlations. The mean values for σ°_{obs} are higher for these fields, which is not surprising considering that there is more plant matter and water interacting with the radar waves. The model correctly predicts more return from these two denser fields. The other four fields do not show much dependence on planting density in the predicted or observed backscatter. Due to conditions during the summer of 1979, the fields with the lowest planting density grew larger plants than the other fields, and apparently made their canopies as vegetated as the middle planting density.

All of the fields have approximately the same shape to the temporal history of σ°_{obs}. The early season is characterized by quite low returns, followed by a sharp rise in the backscatter as the plant grows. The radar return plateaus by about Day 190, remaining fairly constant for the next twenty days. The end-of-season points, Days 240-254, are slightly lower than the mid-season plateau, with more dependence on the

soil contribution.

The sorghum fields match the model equally as well as the 1979 wheat does. The overall correlation for all fields with VV polarization ranges from 0.80 at 13.0 GHz to 0.84 at 35.6 GHz, with 8.6 and 17.0 GHz having correlations of about 0.83. The HH correlations have a wider range, with best correlation of 0.91 occurring at 8.6 GHz, and then decreasing to 0.76 at 35.6 GHz. The 1980 data will be examined to see if it too has the of the best correlation at 8.6 GHz, HH.

4.3 1979 Corn

The regression analysis was performed as for the 1979 sorghum. Individual frequencies and polarizations have their own constants, and all fields were analyzed at the same time. The resulting constants appear in Table 4.3. The 1979 corn data correlate well with the model, with a few exceptions. Generally, VV polarization exhibits a higher correlation between the observed and predicted values than do the HH polarization correlations. The overall correlation between the observed data and predicted values for VV is 0.82, while for HH it is 0.75. Due to the small number of samples for any one field, frequency, and polarization combination, there are two occasions where the correlation drops as low as 0.43. The low correlations are not too serious considering the measurement uncertainty and the lumped field analysis. Both of the low correlations occur on Field C-13. Supplemental notes on the fields describe two of the six fields as having low plant populations and splotchy planting, and analyzing all the fields together allows us to

TABLE 4.3
Manhattan Agricultural Experiment
Model Coefficients and Correlations
between Predicted and Observed σ^o
1979 Corn Fields C-11 - C-16

VV Polarization

FREQ(GHz)	A_{leaf}	B_{stalk}	C_{soil}	D	E
8.6	0.1667	0.0020	0.3388	3.0470	0.4464
13.0	0.1360	0.0029	0.4008	3.7740	0.5426
17.0	0.1775	0.0010	0.5000	3.7850	0.5576
35.6	0.1925	0.0010	0.2917	5.0000	0.4000

FREQ(GHz)	ρ_{11}	ρ_{12}	ρ_{13}	ρ_{14}	ρ_{15}	ρ_{16}
8.6	0.924	0.912	0.912	0.916	0.925	0.826
13.0	0.983	0.962	0.831	0.881	0.796	0.803
17.0	0.918	0.925	0.938	0.760	0.940	0.832
35.6	0.890	0.853	0.807	0.700	0.943	0.959

HH Polarizartion

FREQ(GHz)	A_{leaf}	B_{stalk}	C_{soil}	D	E
8.6	0.1482	0.0001	0.4381	6.3990	0.5268
13.0	0.1100	0.0001	0.3497	4.2280	1.0020
17.0	0.1508	0.0001	0.7000	7.4920	0.6820
35.6	0.1871	0.0001	0.7000	9.9370	0.3435

FREQ(GHz)	ρ_{11}	ρ_{12}	ρ_{13}	ρ_{14}	ρ_{15}	ρ_{16}
8.6	0.912	0.852	0.921	0.965	0.819	0.904
13.0	0.887	0.771	0.572	0.687	0.947	0.919
17.0	0.805	0.721	0.807	0.721	0.670	0.700
35.6	0.934	0.627	0.431	0.948	0.938	0.969

treat all the fields as equals. Limiting the analysis in this manner has also limited the model's ability to correlate with these two cases.

Three frequency trends can be identified:

1) A_{leaf} increases with frequency,

2) D increases with frequency, and

3) E decreases slightly with increasing frequency.

The first two trends are consistent with the model, but the third, like that for the other crops in 1979, is contrary. In all cases, B_{stalk} is very small and contributes very little. The soil coefficient is higher for HH than for VV, although in both cases the contribution from the soil is not significant after Day 180. The estimate for the soil coefficient is susceptible to errors in the Day 150-170 data sets.

The stalk attenuation coefficient, D, is higher for HH than VV. While this trend goes against the model, the estimates of the standard deviations for this coefficient are large and therefore indicate that the coefficients could be significantly different. In all cases, D is substantial and the combination of C, D, and E make the σ^{o}_{soil} term inconsequential after the very early part of the season. While the difference in the constants for HH and VV is large, the effect on the soil term for the two polarizations is almost identical because of the exponential form of E_{2}, the stalk attenuation. The polarization trend may not in itself be correct, but the end effect is correct.

The decrease in E with increasing frequency is not as pronounced with VV as with HH. Due to the relatively high values of D, this constant does not have to respond in order to attenuate the soil term. Primarily, it influences the amount of the early contribution due to the

leaves and therefore is determined by the Day 170-190 period.

The number of data points per field, the error in the data, and the analysis of all the fields in one group masks any field dependence. A comparison of the backscatter from the different fields reveals a trend toward higher mean σ°_{obs} from the more densely planted fields. The correlations between the radar data and LAI and W are higher with higher planting densities, supporting the idea that the canopy attenuates the underlying soil. The same reasoning predicts that the lower the planting density, the greater the dependence on σ°_{soil}. Unfortunately, more early data were collected on the most densely planted field, and as a result, that field has the highest σ°_{obs}-to-m_s correlation.

Except for these correlation trends, the observed backscatter has very little planting-density dependence. The model shows slightly more dependence by having slightly higher σ°_{leaf} values on the more densely planted, larger LAI fields.

The model fits the 1979 corn data well but is surprising in that it does not evidence any appreciable contribution by the stalk. While the stalk water does have a sizable effect in attenuating the soil contribution, the model does not include any backscatter from the stalks. The combination of sizable attenuation and a lack of backscatter is quite odd. The stalks would have to be very good absorbers, causing high loss with little reflection in order to explain this phenomenon. The water in the stalks should cause reflections along with the loss. This shortcoming will be investigated further using the 1980 corn data.

The correlation coefficients for the corn are not quite as good as for the other 1979 crops. The VV cases are quite good (0.86 to 0.89)

with the exception of the 17.0-GHz case (0.77). The HH cases are varied: 8.6 and 35.6 GHz have quite acceptable correlations of 0.87 and 0.86 respectively, but 13.0 and 17.0 GHz have much lower overall correlations (0.71 and 0 70). This variance in the correlations makes the choice of best frequency and polarization difficult. The only conclusion that can be drawn from the corn data is that the model works best with VV polarization.

4.4 1980 Sorghum

The model fits the 1980 sorghum data quite well. The regression analysis was performed for each field, frequency, and polarization separately. The resulting values for the coefficients are listed in Table 4.4 and Appendix D, along with the correlation coefficients between the predicted and observed σ°. The correlation coefficients are all above 0.84, with the best overall correlations being for 17.0 GHz, VV. The average of all the correlation coefficients is 0.92.

Using Field S-33, VV polarization, as an example, the data and predicted values are plotted in figures 4.2, a-d. The component parts of the predicted backscatter are also plotted in these figures. The three contributions behave as expected. For all frequencies the soil term is dominant early, and has very little importance after Day 175. The leaf term rises the most quickly, and by Day 185 has reached its plateau. In the most cases the stalk term rises much more slowly, increasing steadily until Day 230 and then holding constant.

Table 4.4a
Manhattan Agricultural Experiment
Model Coefficients and Correlation between
Predicted and Observed σ^{o} for 1980 Sorghum

VV Polarization

Field	Freq (GHz)	A_{leaf}	B_{stalk}	C_{soil}	D	E	ρ
S-31	8.6	0.0945	0.0530	0.1995	5.0000	1.5067	0.9308
	13.0	0.1214	0.0450	0.2022	5.0000	1.3300	0.9199
	17.0	0.1450	0.0310	0.1442	5.0000	1.4671	0.9522
	35.6	0.1575	0.0001	0.1057	0.5052	1.1138	0.8995
S-32	8.6	0.0693	0.0725	0.1677	5.0000	2.0050	0.9005
	13.0	0.1160	0.0769	0.2168	5.0000	1.4130	0.9358
	17.0	0.1022	0.1105	0.1848	5.0000	0.9420	0.9233
	35.6	0.1747	0.0159	0.1000	5.4710	1.6560	0.9501
S-33	8.6	0.0976	0.0619	0.1478	5.0000	1.9230	0.8442
	13.0	0.1321	0.0450	0.1510	5.0000	1.4680	0.9178
	17.0	0.1257	0.0903	0.1663	5.0000	1.2550	0.9514
	35.6	0.2156	0.0001	0.1479	0.6855	0.7871	0.9133

Table 4.4b
Manhattan Agricultural Experiment
Model Coefficients and Correlation between
Predicted and Observed σ° for 1980 Sorghum

HH Polarization

Field	Freq (GHz)	A_{leaf}	B_{stalk}	C_{soil}	D	E	ρ
S-31	8.6	0.0981	0.0420	0.2040	5.0000	1.2500	0.9437
	13.0	0.1185	0.0220	0.1536	5.0000	1.2020	0.9361
	17.0	0.1342	0.0250	0.1669	5.0000	1.4033	0.9226
	35.6	0.1621	0.0001	0.1299	0.3596	1.0640	0.8954
S-32	8.6	0.0874	0.0808	0.1849	5.0000	1.7340	0.8955
	13.0	0.1193	0.0385	0.1454	5.0000	1.7170	0.9375
	17.0	0.1047	0.0938	0.2014	5.0000	1.4460	0.9025
	35.6	0.1649	0.0318	0.1371	5.5000	1.4880	0.9478
S-33	8.6	0.0901	0.0900	0.1805	5.0000	1.8130	0.9017
	13.0	0.1297	0.0220	0.1032	5.0000	1.3090	0.9571
	17.0	0.1443	0.0308	0.1124	5.0000	1.3320	0.9481
	35.6	0.1914	0.0001	0.1287	0.0001	1.0550	0.8617

Figure 4.2a. Comparison of predicted and observed Sigma0 vs date for 8.6 GHz, VV, 1980 sorghum S-33.

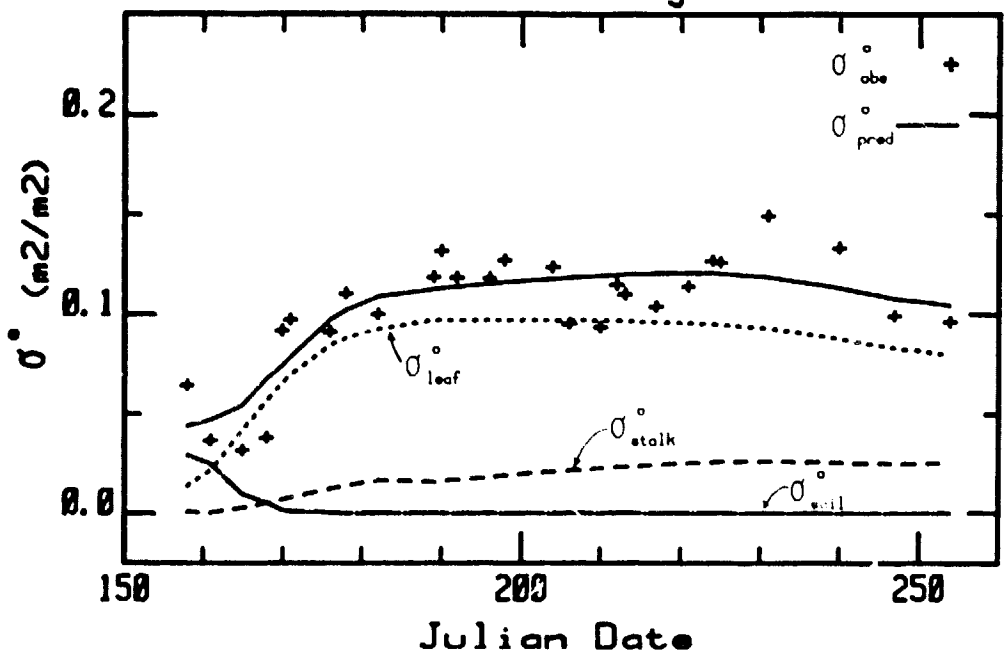


Figure 4.2b. Comparison of predicted and observed Sigma0 vs date for 13.0 GHz, VV, 1980 sorghum S-33.

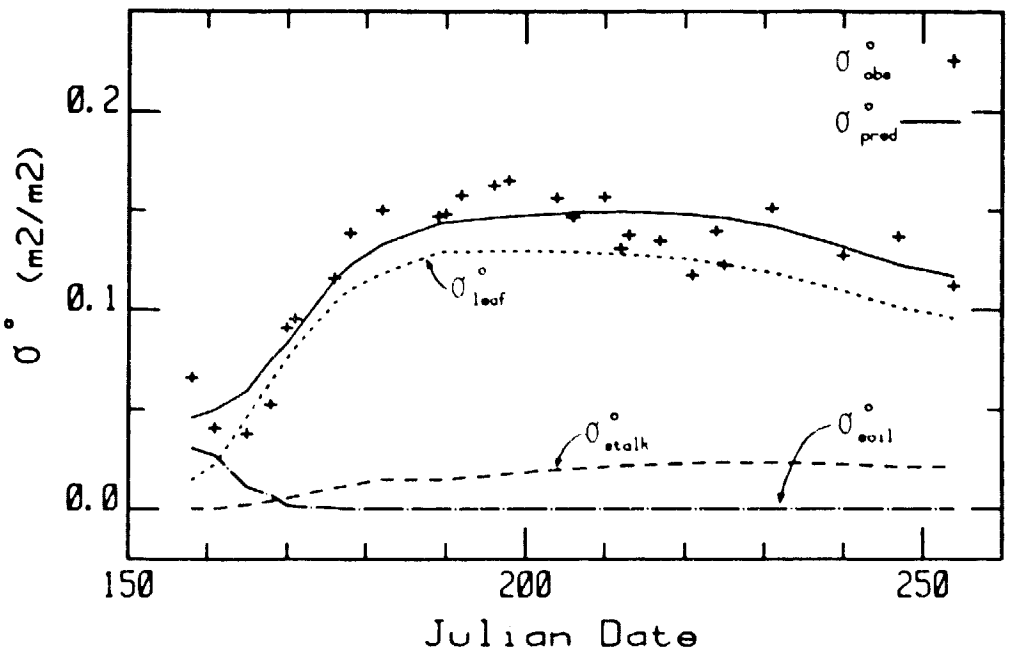


Figure 4.2c. Comparison of predicted and observed Sigma0 vs date for 17.0 GHz, VV, 1980 sorghum S-33.

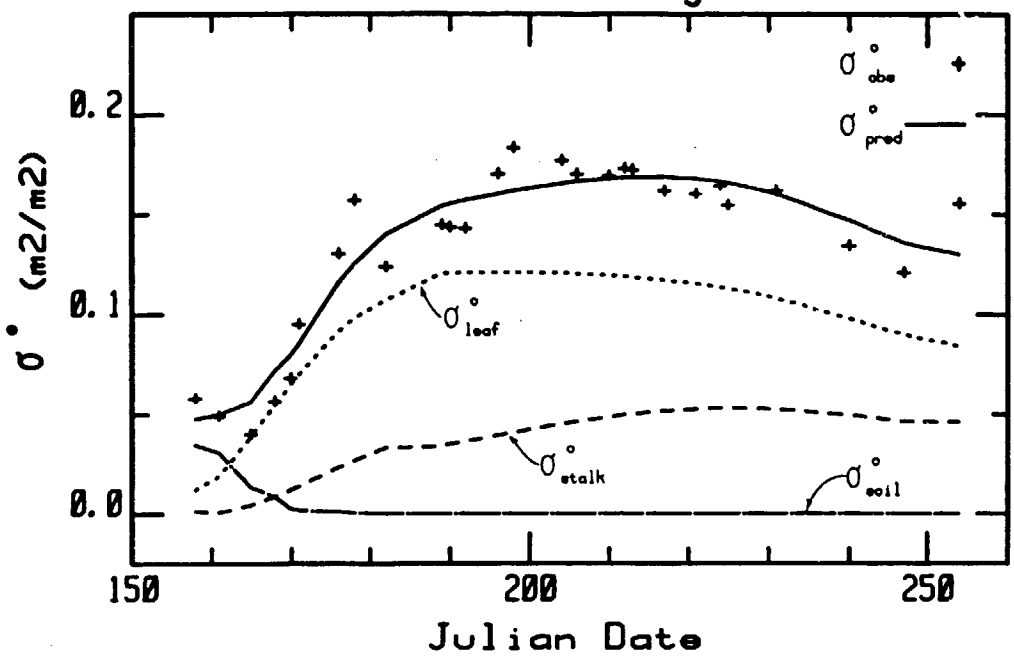
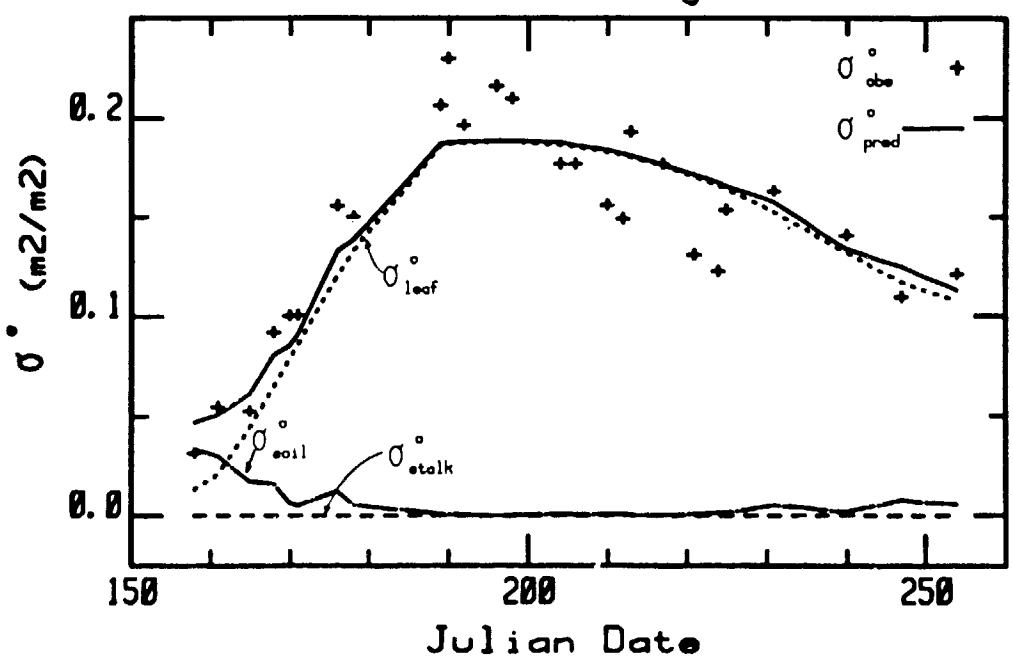


Figure 4.2d. Comparison of predicted and observed Sigma0 vs date for 35.6 GHz, VV, 1980 sorghum S-33.



Field S-33 was further analyzed in the same manner as the 1979 wheat data. These additional coefficients are presented in Table 4.5. The coefficients were constrained by a linear dependence on wavelength, and for increasing frequency:

1) A_{leaf} increases,

2) B_{stalk} decreases,

3) C_{soil} decreases,

4) D increases slightly, and

5) E decreases slightly.

The first four trends support the model, but the change in leaf attenuation still is an anomaly. Comparing the results for the two polarizations, the data weakly support the model. In the 8.6- and 13.0-GHz cases, the leaf coefficient is higher for VV than for HH. The size and orientation of the leaves could be causing this difference, with the canopy appearing to be rougher and more random at the higher frequencies.

Other support for the model can be gathered from Tables 4.4 and 4.5. With the wavelength constraint, the stalk attenuation is much larger for VV than HH. The stalks are vertical, so they should couple with VV better. Referring to Table 4.4, it is apparent that the stalk coefficient B_{stalk} is quite large for both polarizations at 8.6, 13.0, and 17.0 GHz. The 35.6 GHz data, though, exhibit much lower B_{stalk}, implying that the high frequency does not get through the leaves and therefore does not experience a contribution from the stalk. Again this is consistent with the model.

Table 4.5
Manhattan Agricultural Experiment
Model Coefficients and Correlation between
Predicted and Observed σ^o with Linear Wavelength Constraint
for 1980 Sorghum S-33

VV Polarization

Freq (GHz)	A_{leaf}	B_{stalk}	C_{soil}	D	E	ρ
8.6	0.1035	0.0419	0.1532	5.0000	1.7113	0.8411
13.0	0.1445	0.0254	0.1392	5.0000	1.4010	0.9225
17.0	0.1663	0.0178	0.1331	5.0000	1.2584	0.9373
35.6	0.1953	0.0049	0.1229	5.0000	1.0161	0.9058

HH Polarization

Freq (GHz)	A_{leaf}	B_{stalk}	C_{soil}	D	E	ρ
8.6	0.0970	0.0520	0.1811	0.0225	1.0946	0.8817
13.0	0.1326	0.0315	0.1360	0.0745	1.1966	0.9575
17.0	0.1490	0.0220	0.1152	0.0985	1.2435	0.9485
35.6	0.1769	0.0060	0.0799	0.1391	1.3232	0.8562

In comparing the three different fields, the model does not predict the different densities or different yields. Examples of the predicted values for all three fields are presented in Figures 4.3, a-d. The only two periods in which the sorghum fields differ are the beginning (Days 155-180) and the end (Days 230-255). The densest field, S-31 displays a more rapid rise to its plateau value, indicating that the effective coverage of the plants over the soil happens more quickly with a denser field. The figures also show the densest field continuing to mask the soil for a longer time than the other fields.

The densest field, S-31, had the lowest yield. For the four frequencies and two polarizations, this field had the middle value for A_{leaf} and approximately the same σ°_{leaf} contribution as the other two fields. The averaged, observed backscatter from this field was also larger than that for the medium dense field, S-32, but not as large as that for the most productive field, S-33. The model does follow the observed data, but unfortunately the observed data do not show a direct dependence on the planting density of a given field.

The most productive field was the least-dense field and it had the highest A_{leaf} values. This field produced the highest return only at 35.6 GHz, and only during mid-season. The 35.6-GHz case is more sensitive to the top part of the canopy, where the sorghum head is, so it is reasonable that this frequency responds to the greater yield. The σ°_{stalk} term for this case is not distinguishably larger than that for the other fields so the model does not respond particularly well to this test. The regression analysis should to have shown this field to have the largest return from the stalk and head.

Figure 4.3a. Comparison of predicted Sigma0 vs date for all 1980 sorghum fields, 8.6 GHz, VV.

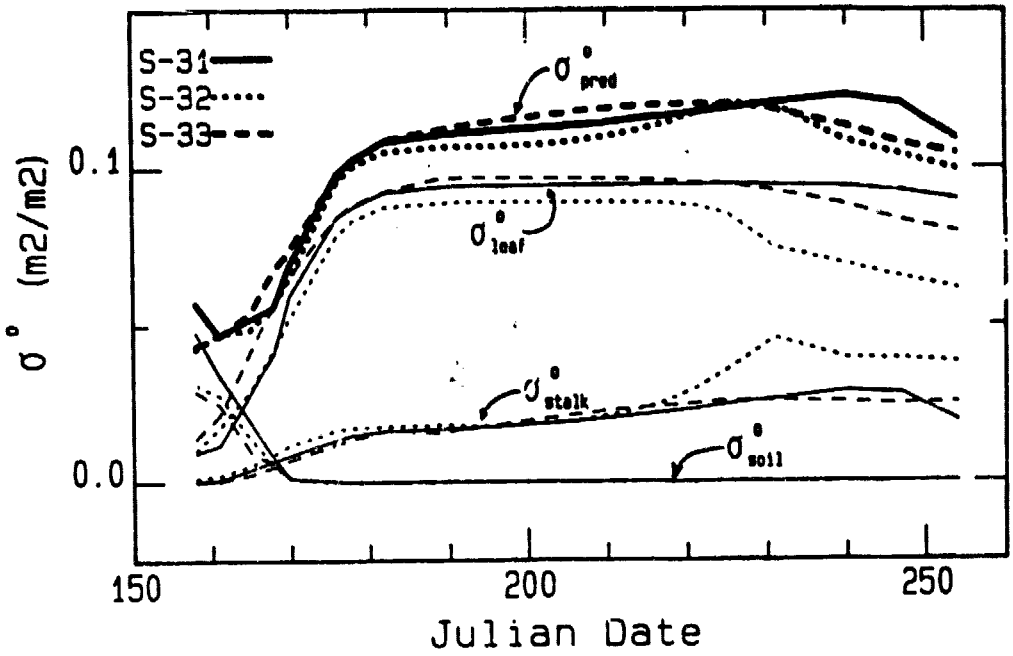


Figure 4.3b. Comparison of predicted Sigma0 vs date for all 1980 sorghum fields, 13.0 GHz, VV.

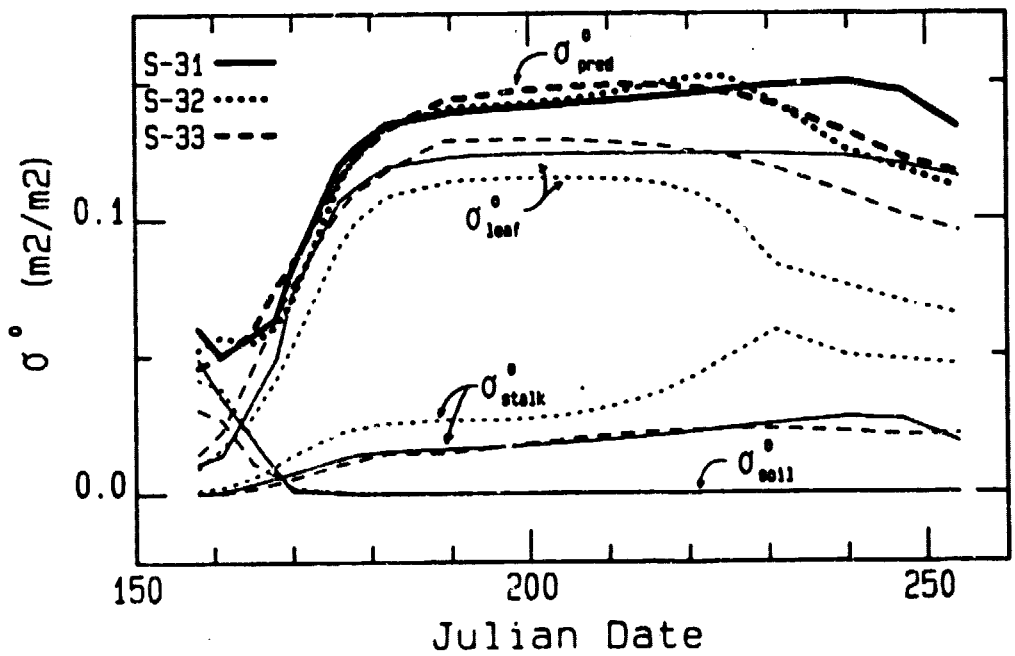


Figure 4.3c. Comparison of predicted Sigma0 vs date for all 1980 sorghum fields, 17.0 GHz, VV.

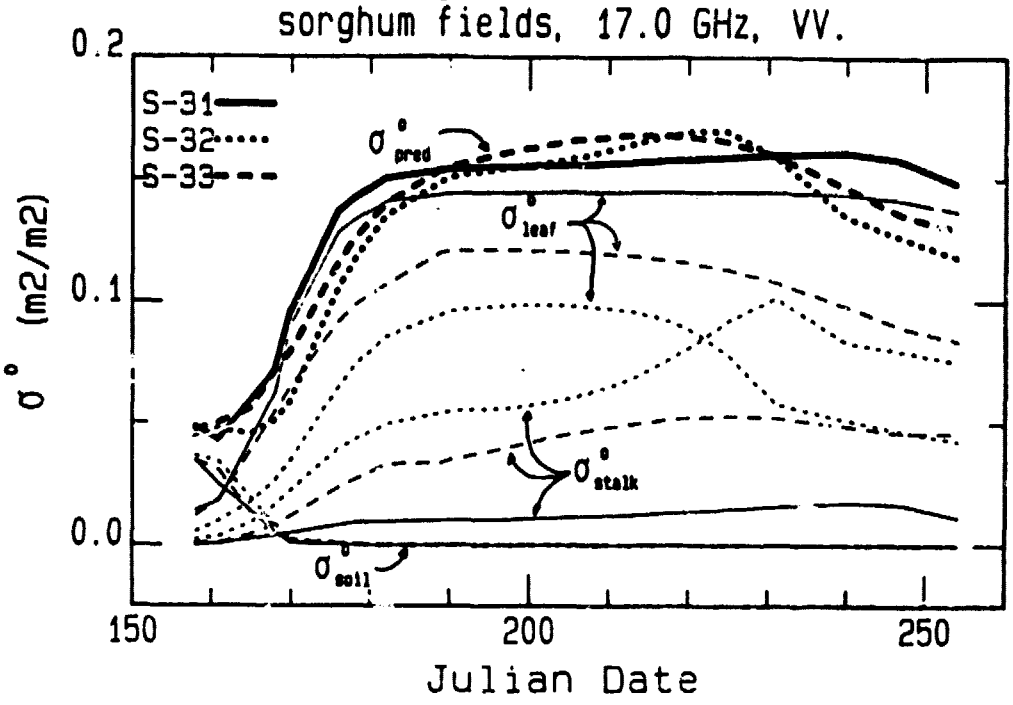
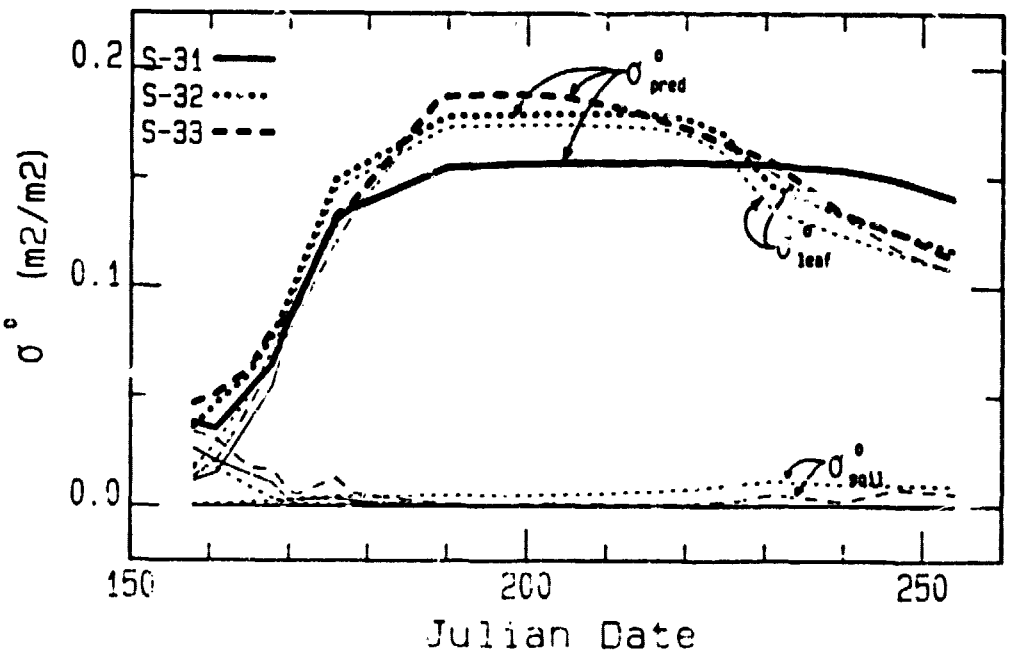


Figure 4.3d. Comparison of predicted Sigma0 vs date for all 1980 sorghum fields, 35.6 GHz, VV.



The middle-density field, S-32, also produced the second largest yield, and on average, had the lowest values for A_{leaf}. However, the σ^{o}_{pred} values are almost the same as the other two. So again, the observed data and the model do not predict the planting density of the field.

4.5 1980 Corn

Of all the crop and year combinations, the 1980 corn data fits the model least well. The mediocre results give some insight into how the model might be improved, and hence this crop comparison is very interesting. The model coefficients and their relative correlation coefficients are listed in Table 4.6a and 4.6b. The correlation coefficients vary between 0.69 and 0.94, with the 8.6-GHz data representing the worst fit and the 35.6 GHz data the best fit. The general shape of the predicted backscatter curve simply does not follow the general shape of the data. The problem with fitting these data centers on two time periods: the first between Days 170 and 190, and the second between Days 210 and 230. The model has assigned the leaf attenuation constant E to be so large that the model, during the latter period, does not slope downward as the data points do. The regression analysis has made this choice for E in order to match the sharp rise in the Day 150-170 data, and the outcome is that the leaf term remains high for too long, in a saturated state.

Efforts to make the model track the LAI in the latter period resulted in correlations that were not as good as those presented in

Table 4.6a
Manhattan Agricultural Experiment
Model Coefficients and Correlation between
Predicted and Observed σ^0 for 1980 Corn

VV Polarization

Field	Freq (GHz)	A_{leaf}	B_{stalk}	C_{soil}	D	E	ρ
C-11	8.6	0.1256	0.0010	0.3222	0.0100	1.3312	0.7876
	13.0	0.1740	0.0010	0.3295	0.0100	1.0745	0.8726
	17.0	0.1998	0.0010	0.3450	0.0991	0.8000	0.8681
	35.6	0.2076	0.0010	0.2654	0.1000	0.9967	0.8758
C-12	8.6	0.1640	0.0001	0.2639	0.0001	0.9281	0.8910
	13.0	0.1936	0.0001	0.3050	0.0001	1.1165	0.8223
	17.0	0.2012	0.0033	0.3144	0.0001	1.4182	0.8337
	35.6	0.1890	0.0236	0.1000	0.0001	1.1501	0.9415
C-13	8.6	0.1360	0.0001	0.2200	0.0001	0.9810	0.8122
	13.0	0.1669	0.0001	0.2660	0.1912	0.9000	0.9018
	17.0	0.1867	0.0001	0.2937	0.2863	0.9000	0.8914
	35.6	0.2335	0.0001	0.2000	0.1622	0.9584	0.8875

Table 4.6b
Manhattan Agricultural Experiment
Model Coefficients and Correlation between
Predicted and Observed σ^o for 1980 Corn

HH Polarization

Field	Freq (GHz)	A_{leaf}	B_{stalk}	C_{soil}	D	E	ρ
C-11	8.6	0.1219	0.0010	0.3927	0.0100	1.3501	0.6942
	13.0	0.1524	0.0020	0.4230	0.0100	1.0656	0.7322
	17.0	0.1826	0.0010	0.3567	0.0529	0.8000	0.8178
	35.6	0.2109	0.0010	0.3193	0.1000	1.0022	0.8196
C-12	8.6	0.1496	0.0001	0.3582	0.0001	1.0555	0.7908
	13.0	0.1798	0.0045	0.3441	0.0001	0.9886	0.8305
	17.0	0.2120	0.0001	0.3496	0.0001	0.8022	0.8636
	35.6	0.1741	0.0275	0.1000	0.0001	1.3022	0.9235
C-13	8.6	0.1199	0.0001	0.3445	0.0001	1.3694	0.8412
	13.0	0.1482	0.0001	0.3262	0.1202	0.9000	0.8687
	17.0	0.1706	0.0001	0.3932	0.3029	0.9000	0.8809
	35.6	0.2181	0.0001	0.2161	0.0624	1.1473	0.9027

Table 4.6. The inclusion of an LAI in the leaf term, thus producing a σ°_{leaf} of the same form as that in the wheat model, resulted in a better fit to the downward-sloping curve during the Day 210-230 period. Unfortunately, this added dependence resulted in the consequence that the model no longer fitted the early rise. The model was also changed in other ways. Notice that the B_{stalk} coefficients in Table 4.6 are all quite low. The model rejected any stalk contribution in order to fit the data. The model was revised to allow the stalk term to have a different, separate leaf-attenuation constant in order to allow the model to increase the stalk contribution and to change the overall temporal shape of the predicted backscatter. Still, the regression analysis rendered σ°_{stalk} insignificant relative to σ°_{leaf}. Even with the additional freedom of another constant, the correlations were no better. In addition, the general shape of the model was no closer to fitting the data.

Examples of the model's fit are in Figures 4.4,a-d. Again, the data is plotted along with the predicted values and its components. Notice how the model has ignored the contribution from the stalk, causing it to be zero in all cases. Due to the low late-season values, the stalk contributions were discarded. In order to match the very early and very late periods of the season the soil moisture term must be large, causing the model to discard the σ°_{stalk} term. The main plateau is predominantly leaf-controlled when it should be a combination of leaf and stalk terms. This model is unable to reduce the stalk contribution term sufficiently in the late season, and is forced to make B_{stalk} almost zero.

Figure 4.4a. Comparison of predicted and observed Sigma0 vs date for 8.6 GHz, VV, 1980 corn C-13.

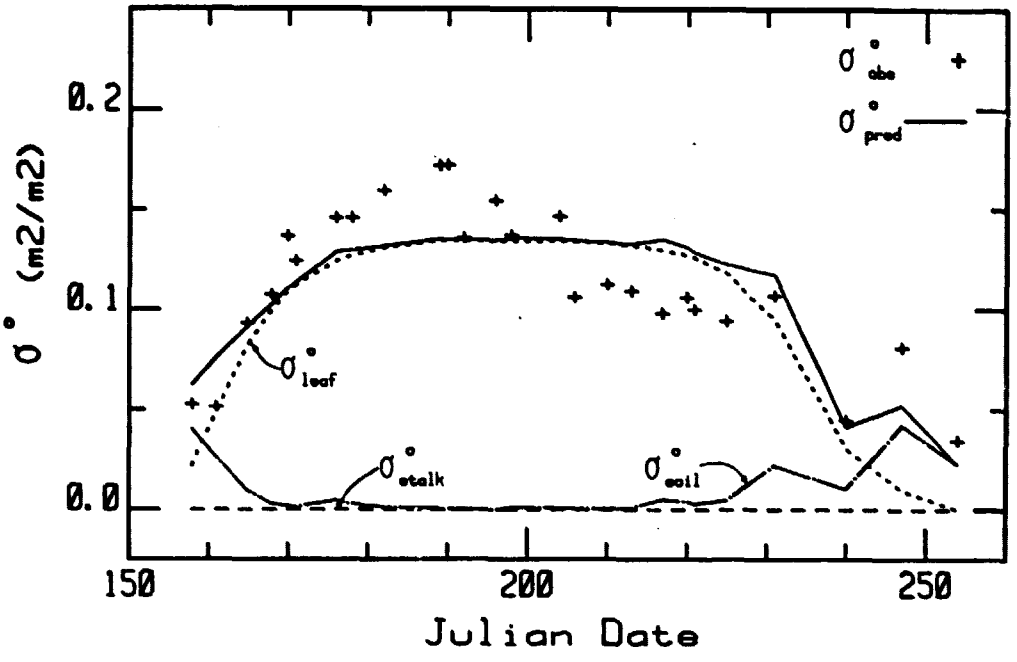


Figure 4.4b. Comparison of predicted and observed Sigma0 vs date for 13.0 GHz, VV, 1980 corn C-13.

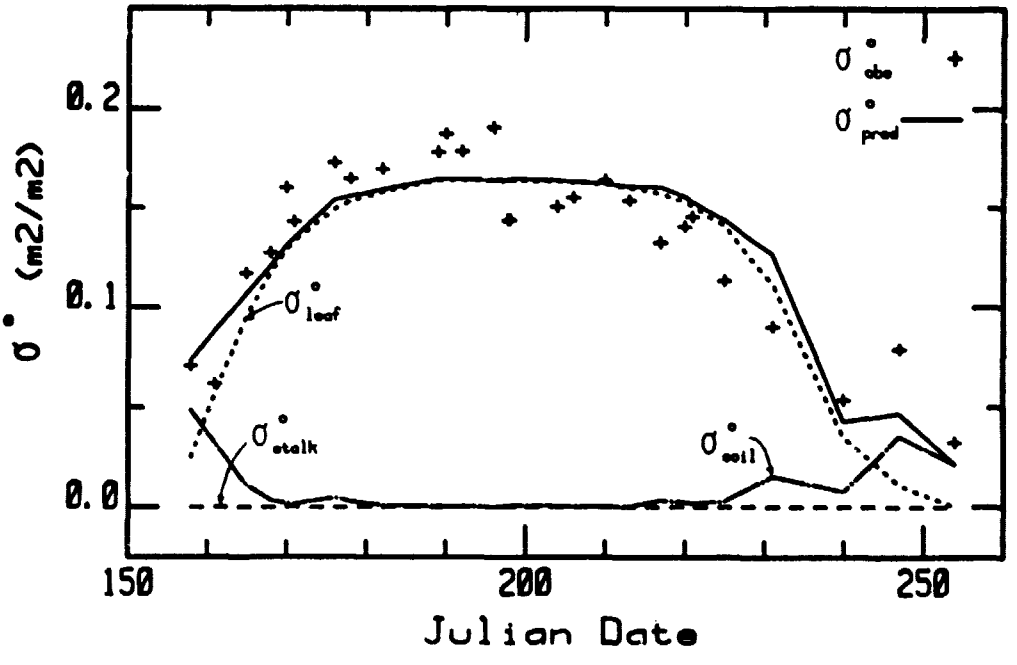


Figure 4.4c. Comparison of predicted and observed Sigma0 vs date for 17.0 GHz, VV, 1980 corn C-13.

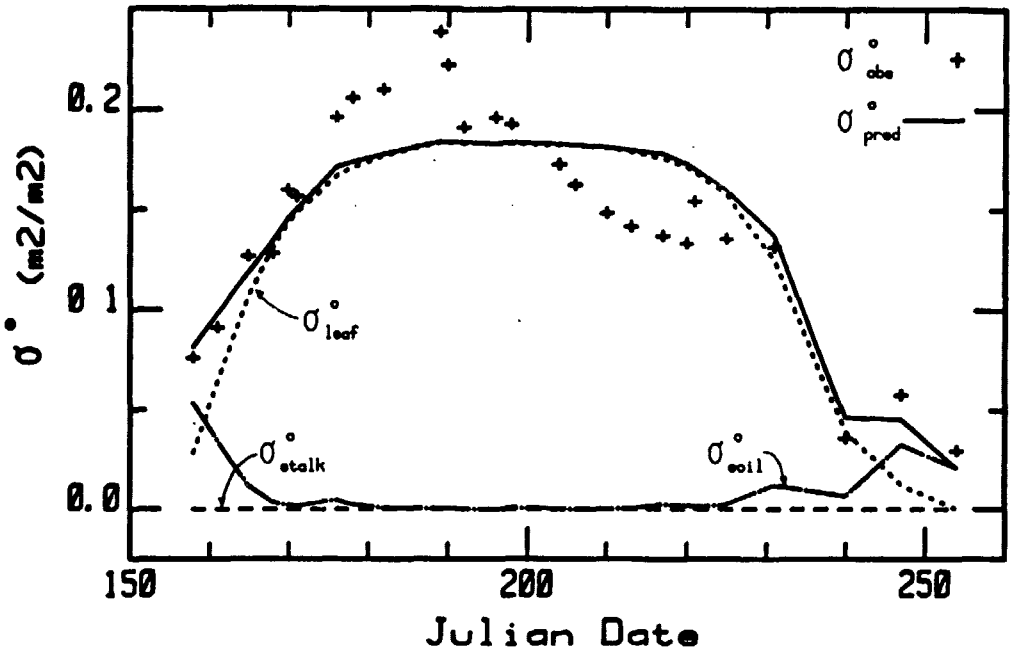


Figure 4.4d. Comparison of predicted and observed Sigma0 vs date for 35.6 GHz, VV, 1980 corn C-13.

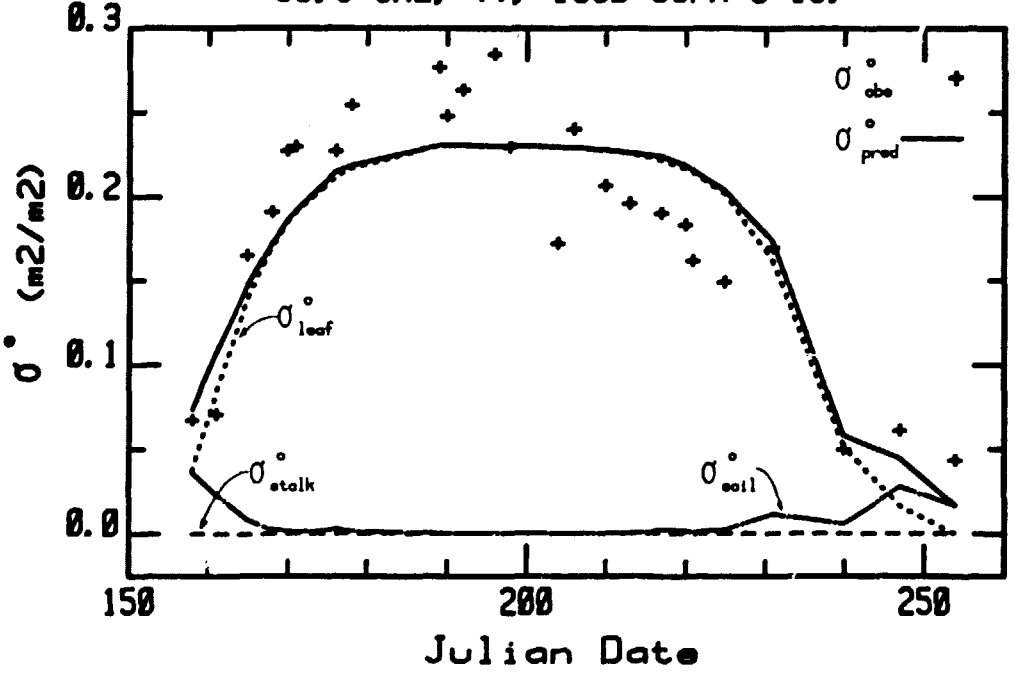


Table 4.7
Manhattan Agricultural Experiment
Model Coefficients and Correlation between
Predicted and Observed σ^o with Linear Wavelength Constraint
for 1980 Corn C-13

VV Polarization

Freq (GHz)	A_{leaf}	B_{stalk}	C_{soil}	D	E	ρ
8.6	0.1344	0.0001	0.2668	0.0620	0.7794	0.8057
13.0	0.1756	0.0001	0.2513	0.1612	0.8509	0.9040
17.0	0.1945	0.0001	0.2442	0.2068	0.8837	0.8911
35.6	0.2267	0.0001	0.2320	0.2842	0.9395	0.8866

HH Polarization

Freq (GHz)	A_{leaf}	B_{stalk}	C_{soil}	D	E	ρ
8.6	0.1162	0.0001	0.3895	0.0408	0.8041	0.7977
13.0	0.1581	0.0001	0.3385	0.1348	0.9154	0.8691
17.0	0.1774	0.0001	0.3152	0.1781	0.9666	0.8752
35.6	0.2101	0.0001	0.2755	0.2516	1.0535	0.9008

Analyzing C-13 separately for frequency trends, the model was again applied with linear constraints on the coefficients dependent on wavelength. The coefficient trends, as Table 4.7 shows, again support the model. With increasing frequency:

1) A_{leaf} increases,

2) C_{soil} decreases,

3) D increases, and

4) E increases.

The polarization comparison mildy supports the model by making the VV coefficients significantly higher than their HH counterparts. This again supports the idea that the plant geometry should couple better with VV. For both polarizations, the σ^{o}_{pred} contains scarcely any σ^{o}_{stalk}. The VV cases should have a significant stalk contribution.

One explanation for the lack of agreement between the model and the 1980 corn data may be due to the physics of the interaction between the crop and the radar signal. The model uses LAI as the input to the leaf contribution and attenuation. The parameter LAI is defined as the amount of green-leaf area per unit area of ground. This parameter, while related to the amount of water in a plant, does not necessarily indicate the state of the water in the leaves. The amount of backscatter depends both on the number of scatterers and each scatterer's ability to absorb or reflect energy. The dielectric constant determines the amount of reflected energy, and it is in turn dependent on the amount and mobility of the water present in the scatterer. If, early in the season, there was sufficient water available in the plant to fill out its leaves, the radar would respond more strongly. As the

hot, dry, summer of 1980 wore on, the plants were less able to keep the same amount of water in the leaves. The water in the leaves was more tightly bound to the leaves, causing the dielectric constant to decrease. The scattering ability of the plant, while LAI was decreasing somewhat, was actually decreasing very rapidly.

This conjecture suggests that the leaf contribution would be more accurate in years of water stress if another parameter were used to input to the model. The best input would somehow consider both the mobility of the water in the leaves and the number of leaves present. A combination of the LAI and either the leaf water percentage or some other water-retention measurement would be a better indication of both the number and strength of the leaf scatterers.

Comparing the three corn fields in Figures 4.5,a-d, several interesting phenomena stand out. First the medium-dense field, C-11, has the most influence from the soil moisture. All frequencies for this field have small discontinuities that correspond to soil moisture events. While this field did not start out to be the least densely populated, due to weather conditions and irrigation capacities, it was eventually the most water-stressed and sparsely vegetated field. The observed and predicted backscatter values do track the decrease in vegetation and the increase in soil moisture importance. Field C-12 had the lowest planting density and also the second-largest number of discontinuities. This field was the most thoroughly irrigated, so it produced the healthiest and highest-yielding plants. It started out being sparsely vegetated but grew thickly enough to have less dependence on soil moisture. The densest field, C-13, had the smoothest curves.

Figure 4.5a. Comparison of predicted Sigma0 vs date for all 1980 corn fields, 8.6 GHz, VV.

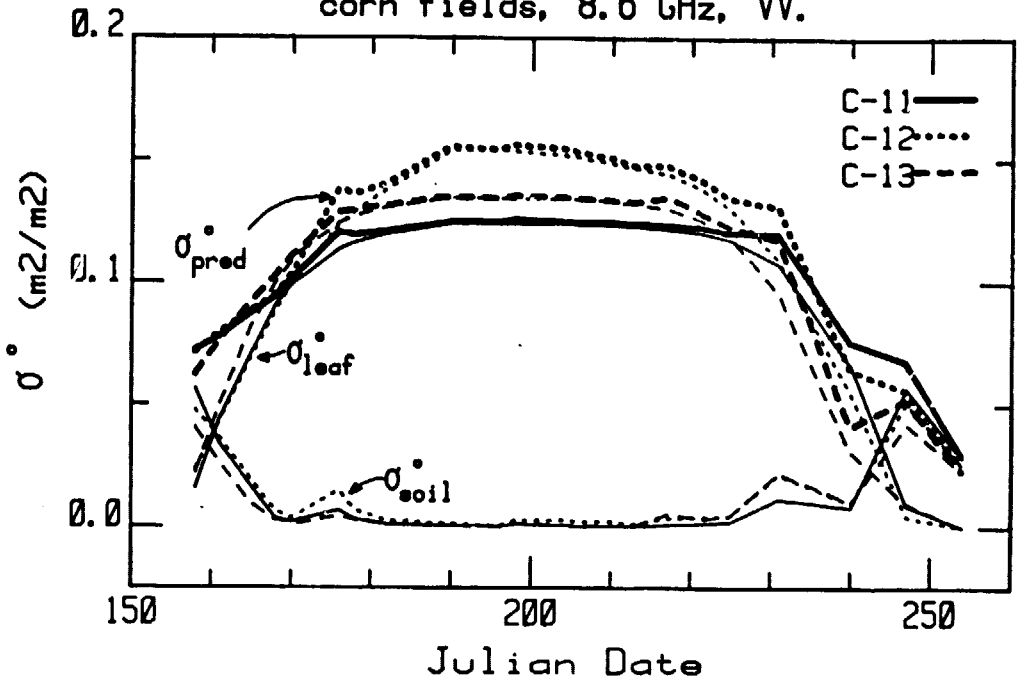


Figure 4.5b. Comparison of predicted Sigma0 vs date for all 1980 corn fields, 13.0 GHz, VV.

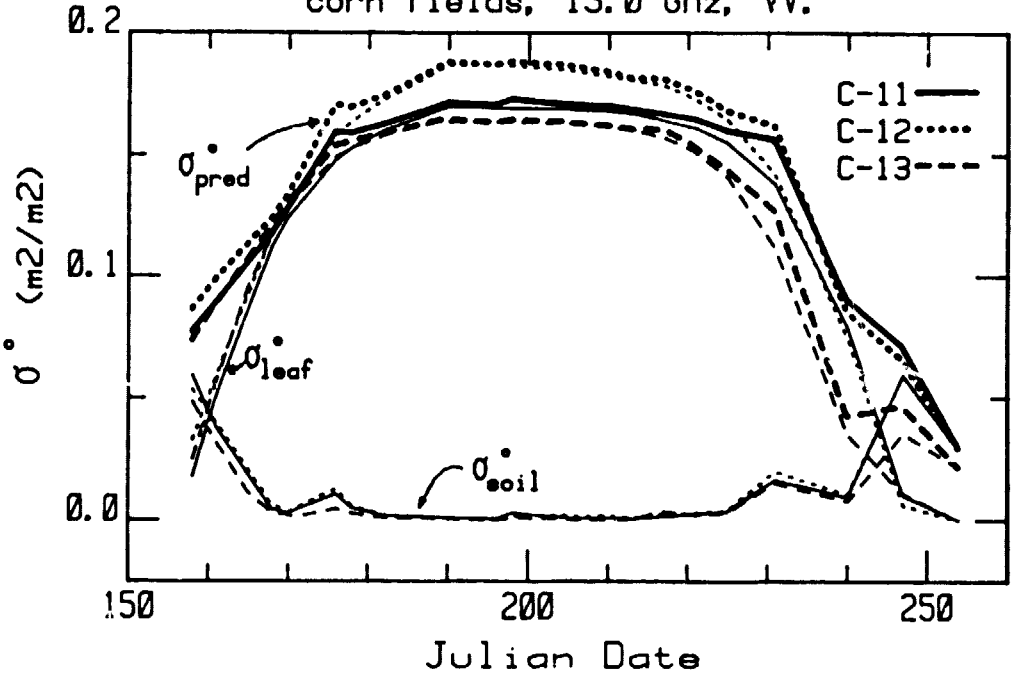


Figure 4.5c. Comparison of predicted Sigma0 vs date for all 1980 corn fields, 17.0 GHz, VV.

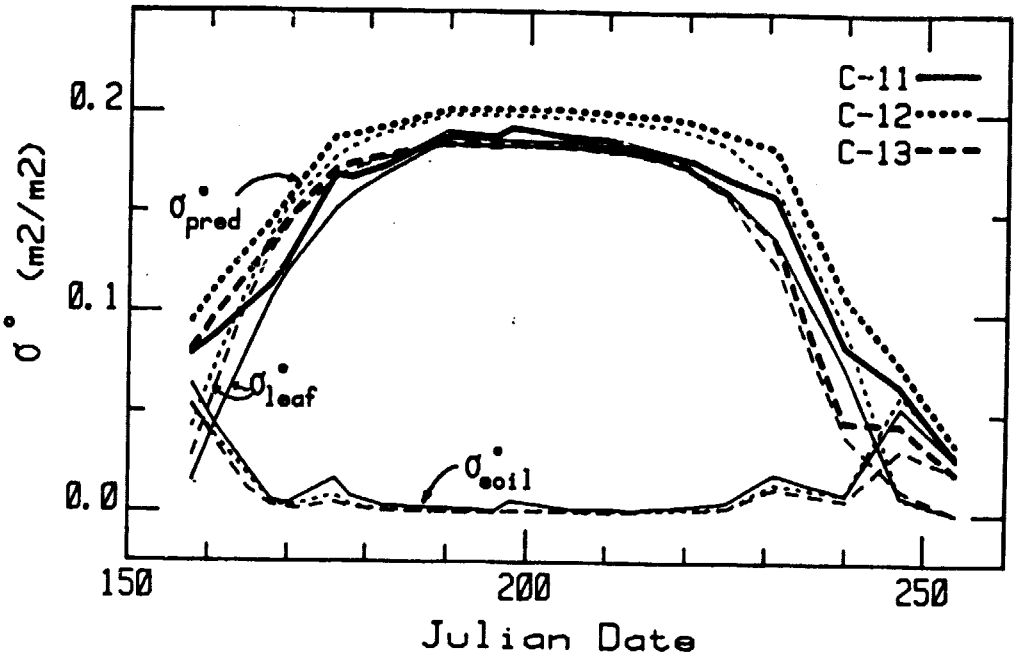
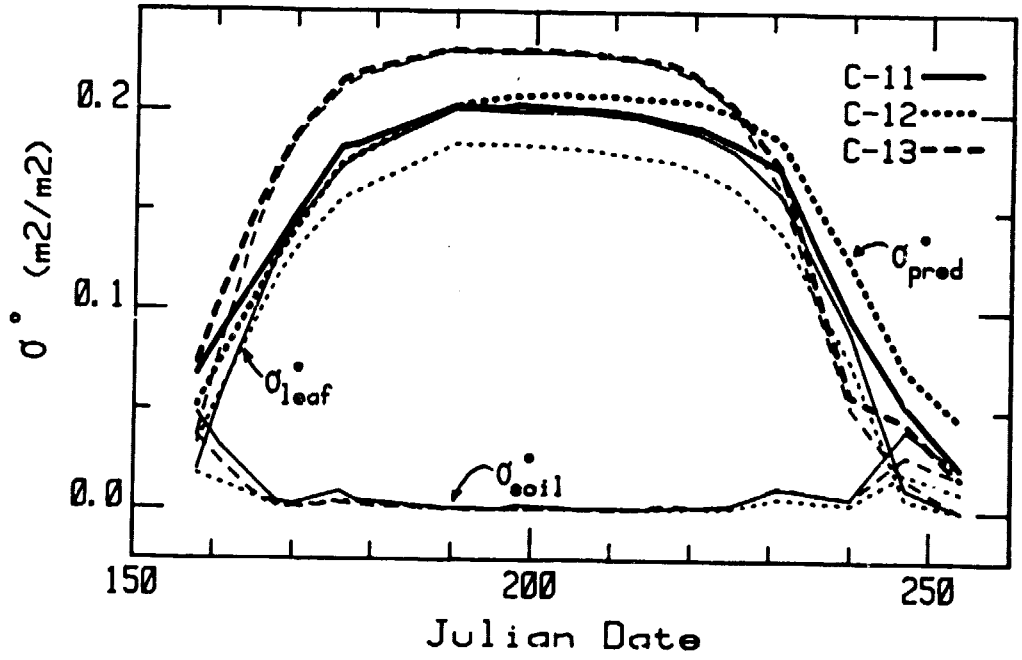


Figure 4.5d. Comparison of predicted Sigma0 vs date for all 1980 corn fields, 35.6 GHz, VV.



If planting density were the only difference between fields, then in Figures 4.5,a-d, one would expect to see C-13 on top, C-11 in the middle, and C-12 on the bottom. This is not the case; in all but the 35.6-GHz case, Field C-12 has the highest return in the middle part of the season. The other two fields are very close together except for C-11, which exhibits a larger late-season return from the soil. The healthier plants in C-12 must have had more water in their leaves, and hence more backscatter. Field C-13, the densest and lowest-yielding field must have undergone water stress, but the top of the plant remained healthy enough to cause the 35.6-GHz cases to remain high. All frequencies show a sharp drop in the Day 231-254 period, indicating that even though the LAI and W are large for this field, the water contained in the leaves must have been less mobile and thus caused less backscatter.

The 1980 corn data contains important information about the model's ability to predict backscatter from water-stressed plants. While the model correctly predicts the early-season trends, it is not capable of predicting the backscatter from drier corn. More work must be done in order to have the model fit this case. New ways of quantifying the mobility of the water in a leaf or more directly, of measuring the average dielectric constant of leaves, are neccesary in order to better characterize the leaf scatterers.

4.6 Comparison of Crops and Years

Comparing the two years of data and the three different crops is not difficult. The wheat data show that wheat can have a much more volatile temporal history, with as much as 12 dB of dynamic range between the full leafy stage and the late mid-season drying stage. The sorghum exhibits an exponential rise to an asymptotic shape, with the initial rise occurring while the plant is growing to its final height and the peak of its leafiness. The sorghum crop stays greener longer, and though it does not generate as much backscatter as corn, the late-season returns do not decline like those for corn. The two years' data expose the differences that can occur under very good and very poor growing climates. The 1979 sorghum backscatter data are much higher than their 1980 counterparts because the much wetter, more agreeable summer of 1979 yielded healthier, more productive plants. A comparison between the data for 1979 sorghum and the data for 1980 sorghum is presented in Figure 4.6. This trend was predicted from the comparison of ground-truth parameters. The agreement with the ground truth indicates the potential for using radar as a crop condition sensor.

The 1979 sorghum data have higher mean values and more dynamic range than the 1979 corn data. Conversely, the 1980 corn data have higher peak- and mean-values than the 1980 sorghum data. The 1979 corn data have approximately the same level for their plateau as the initial peak for the 1980 corn data, as shown in Figure 4.7. The dryness of the 1980 summer caused the 1980 corn backscatter data to droop, while the

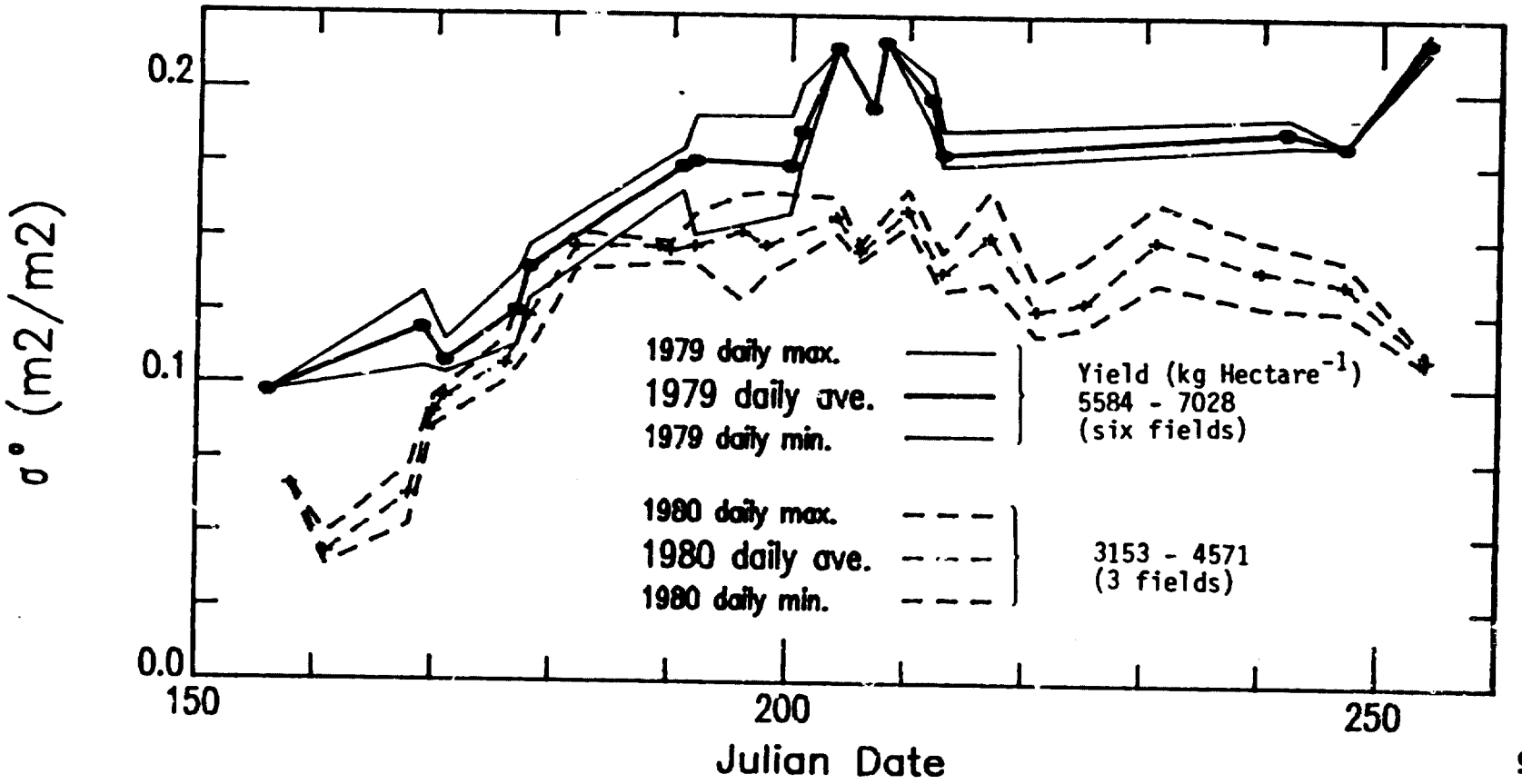


Figure 4.6. Comparison of observed Sigma0 vs date for all 1979 and 1980 sorghum fields, 13.0 GHz, W.

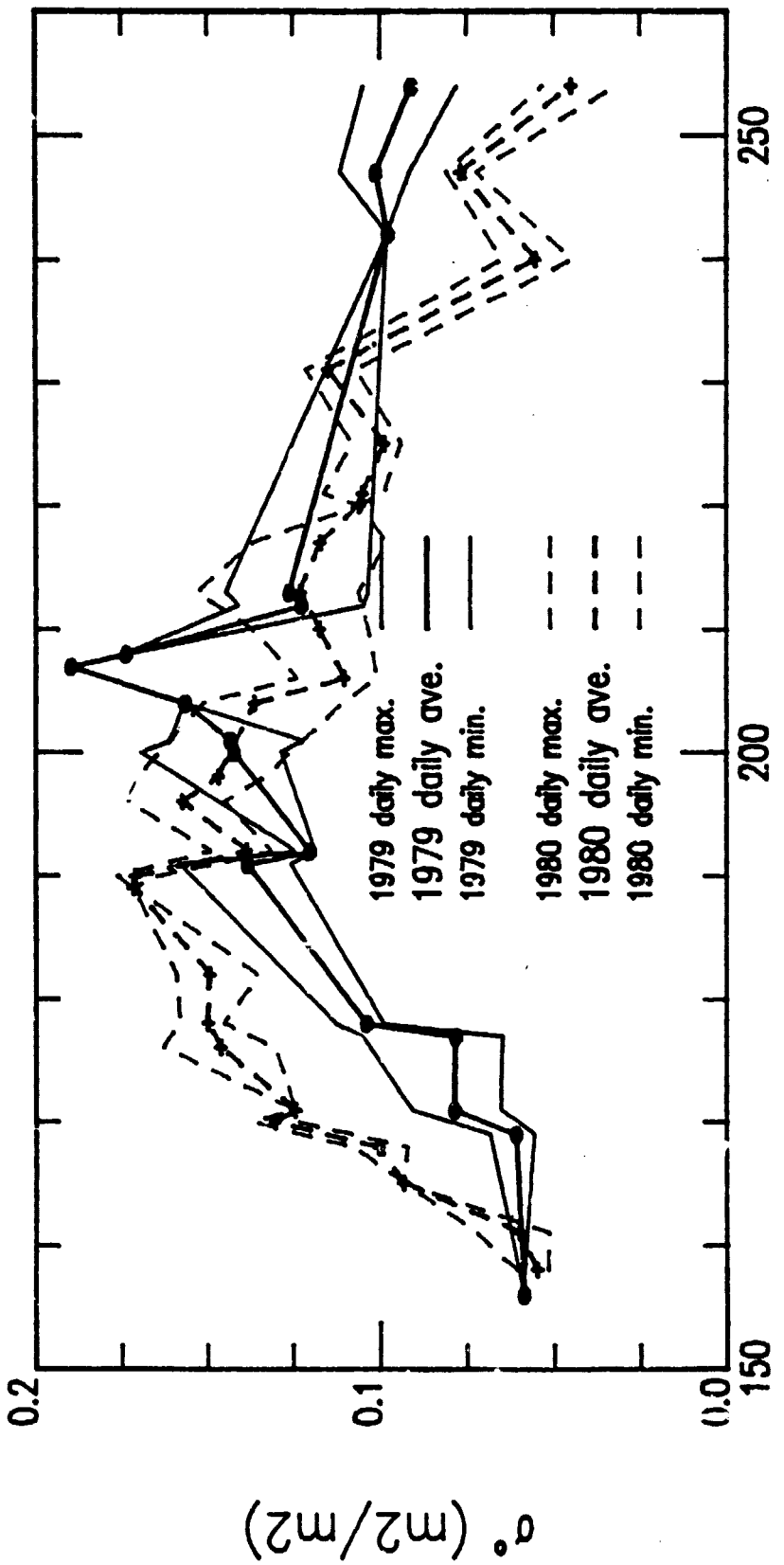


Figure 4.7. Comparison of observed Sigma0 vs date for all 1979 and 1980 corn fields, 8.6 GHz, W.

1979 corn had sufficient water to be healthy and hold the σ^{o}_{obs} values higher longer. The yields were smaller in 1980, and the early sag in the radar data might be an indicator of the health and productivity of the plants.

By looking at the model coefficients and comparing the crops, the following comments can be made about the backscatter from the different crops. Most evident is that the corn stalk does not appear to contribute to the backscatter from that crop. Neither the 1979 nor the 1980 corn data has a significant B_{stalk} value. The corn stalk does play a significant part in the attenuation of the underlying soil's contribution, however. The corn leaves are good reflectors and attenuators, and after the plant is half grown, the backscatter depends almost entirely on the condition and density of the leaves.

Leaf attenuation is larger for 1980, which can be explained by differences that appear in the two years. The 1980 data has more samples in the early season, the period that defines the value of E. The 1979 data has a large spread between Day 178 and 191, with no data. The 1979 σ^{o}_{obs} may have actually reached the mid-season plateau around Day 185, but the next data points do not occur until Days 191 and 192. The 1979 data may have some time-domain sampling error which reduces the value of E for that year.

The second difference between years that could induce different values for E are climatic. The winter of 1979 was fairly cold while 1980 had a mild winter and an early spring. The growth of the plants in 1980 was probably more rapid due to warmer weather and soil conditions. This rapid growth is the most likely cause of the larger peak

for the 1980 corn (Figure 4.7).

Unlike the corn, both the 1979 and 1980 sorghum σ°_{pred} have sizable contributions from the stalks and heads. The stalk coefficient is not as large as the leaf contribution, but in most cases, σ°_{stalk} is 25 percent or more of the total σ°_{pred}. The leaf-attenuation coefficients for the 1979 sorghum are comparable to those for the 1980 sorghum. The LAI values were higher for the 1979 sorghum ground truth than for the 1980 data, resulting in more attenuation on the soil from the leaves in the 1979 predicted values. The stalk attenuation coefficients are larger for the 1980 sorghum data than for the sorghum data in 1979. The stalk attenuation must depend on the amount of water available; with more leaves and leaf attenuation, the amount of stalk attenuation needed to produce the correct soil contribution is smaller. In a dry year such as 1980, the leaves were less watery and the radar penetrated to the stalks. The stalk attenuation was forced to be higher in order to keep the soil term small. The end result for both years and crops is the soil component is unimportant except during the very early and late potions of the season.

5.0. CONCLUSION

The model presented predicts microwave backscatter data from the three crops well. Correlations between the predicted and observed values were higher for wheat and sorghum data than for corn data. The wheat model needs to be tested further using actual head-water content ground truth and additional fields. The model for wheat performed very well during the early part of the growing season, but it did not predict the crop yield or respond to the number and distribution of heads as desired. The sorghum data had good agreement with the model, and the relative contributions of the three parts were fair. Except for the 35.6-GHz cases, the stalk contribution played an important part in the predicted backscatter. The sorghum model can be improved by acquiring more data to better define the attenuation constants D and E.

The corn model, while having good correlation in 1979 and fairly good correlation in 1980, does not fit the 1980 data as to the correct overall shape. This failure requires additional testing of the model to find the source of error. The seasonal trend in overall plant-water percentage might be useful in moderating the LAI parameter in order to obtain a better overall fit. An effective LAI, created by combining percent leaf water content and LAI, should be investigated as an input to the leaf backscatter and attenuation parts of the model.

Overall, the model has fairly consistent frequency and polarization trends. The values for the coefficients are fairly consistent for the two years. The leaf attenuation coefficient does not always behave as expected but because it is primarily dependent on the early-season data

and has a high estimate of variance, the unexpected trends may not be genuine.

The planting density does not correlate well with σ^o. The canopies were not as different as the planting density would indicate. The lower planting-density fields had more robust plants which partially eliminated the planting-density differences.

The backscatter did not indicate which fields would have the best yield. The measured backscatter and model did indicate, however, which fields were more heavily vegetated, but those fields did not always have the highest yield. Particularly in 1980 when the growing conditions were less than ideal, the least heavily vegetated fields produced the highest yields.

The measurements indicate that the wheat crop could be recognized by two characteristics. First, it had the earliest peak due to the LAI term or the leafiness. Second, the peak in the leafiness produced the highest backscatter. The regression analysis indicated two other important trends. The 35.6 GHz data followed the LAI-influenced period best with the largest dynamic range of backscatter values. The model implies that a high frequency radar system is most useful for sensing wheat LAI. Conversely, sensitivity to backscatter influenced by the wheat head is greatest at 8.6 GHz. Thus, when radar data is intended for the prediction of wheat yield, the lower frequency is preferable. The corn fields could possibly be distinguished from the sorghum by the late-season droop that corn exhibited. The sorghum fields are characterized by the flat plateau of their backscatter, even during a dry year.

The correlations were generally better with VV polarization. The data for this polarization were characterized by larger returns and the plant components of the predicted backscatter were larger for VV polarization, suggesting VV polarization would be favorable over HH for monitoring canopy conditions. The difference between the two polarizations decreased as frequency increased, as evidenced by the similarity in the 35.6-GHz cases. The lower frequencies were characterized by more return from the underlying soil and more contribution from the stalks or heads. While the model matched the higher frequencies best, it indicated that for stalk monitoring, frequencies in the 8.6-to-13.0 region are preferable, as the higher frequencies respond better to the leaf effects.

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APPENDIX A - 1979 Wheat Data

Observed values of the backscattering coefficients, predicted values, ground-truth values, and correlation between predicted and observed backscattering coefficients, and model values for two winter wheat fields.

MODEL EQUATION

$$\sigma^o_{pred} = \sigma^o_{leaf} + \sigma^o_{head} + \sigma^o_{soil}$$

$$= A_{leaf} \cdot LAI\ (1 - e^{-E \cdot LAI})\ e^{-D \cdot DWT}$$

$$+ B_{head} \cdot DWT_{head}$$

$$+ C_{soil} \cdot m_s \cdot e^{-D \cdot DWT}\ e^{E \cdot LAI}$$

Symbol	SI Units	Description
σ^o_{pred}	$m^2\ m^{-2}$	Predicted backscattering cross section coefficient
σ^o_{leaf}	$m^2\ m^{-2}$	Backscattering cross section coefficient for leaf contribution
σ^o_{head}	$m^2\ m^{-2}$	Backscattering cross section coefficient for wheat head contribution
σ^o_{soil}	$m^2\ m^{-2}$	Backscattering cross section coefficient for soil contribution
LAI	$m^2\ m^{-2}$	Leaf Area Index
H	m	crop canopy height
W	$kg\ m^{-3}$	Volumetric normalized plant water content
m_s	$kg\ m^{-3}$	Volumetric soil moisture content
A_{leaf}	----	Empirical coefficient for leaf contribution to predicted radar backscatter
B_{head}	----	Empirical coefficient for wheat head contribution to predicted radar backscatter
C_{soil}	----	Empirical coefficient for soil contribution to predicted radar backscatter
D	nepers $m\ kg^{-1}$	Empirical attenuation coefficient for attenuation due to plant water
E	nepers	Empirical attenuation constant for attenuation due to leaves
ρ	----	Correlation coefficient between predicted and observed backscatter coefficients

MANHATTAN AGRICULTURAL EXPERIMENT

1979 WHEAT W-41
8.6 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{head}	σ_{soil}	H	MP	MS	LAI	DWT
116	0.0333	0.0545	0.0399	0.	0.0146	0.410	4.390	0.140	2.150	0.000
121	0.0603	0.1036	0.1028	0.	0.0008	0.460	3.910	0.240	5.100	0.000
128	0.1963	0.1758	0.1758	0.	0.	0.600	6.170	0.160	8.700	0.000
136	0.0741	0.1015	0.1007	0.	0.0007	0.710	3.800	0.200	5.000	0.000
142	0.0336	0.0512	0.0264	0.0171	0.0078	1.020	3.240	0.240	2.600	0.161
149	0.0378	0.0431	0.0113	0.0236	0.0082	1.080	2.870	0.100	1.600	0.222
156	0.0695	0.0484	0.0023	0.0391	0.0070	1.080	2.310	0.060	0.800	0.368
166	0.1409	0.0679	0.	0.0546	0.0133	1.030	1.750	0.080	0.	0.514
173	0.1321	0.1324	0.	0.0375	0.0949	1.030	0.390	0.300	0.	0.353
183	0.1660	0.1065	0.	0.0417	0.0648	0.890	0.450	0.240	0.	0.393

A_{leaf}=0.0202 B_{head}=0.1062 C_{soil}=1.2897 D=3.9798 E=1.1704

CORRELATION COEFFICIENT=0.776

1979 WHEAT W-41
13.0 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{head}	σ_{soil}	H	MP	MS	LAI	DWT
116	0.0411	0.0685	0.0459	0.	0.0226	0.410	4.390	0.140	2.150	0.000
121	0.1422	0.1376	0.1333	0.	0.0043	0.460	3.910	0.240	5.100	0.000
128	0.2223	0.2324	0.2322	0.	0.0002	0.600	6.170	0.160	8.700	0.000
136	0.1151	0.1343	0.1304	0.	0.0038	0.710	3.800	0.200	5.000	0.000
142	0.0380	0.0662	0.0381	0.0105	0.0177	1.020	3.240	0.240	2.600	0.161
149	0.0182	0.0437	0.0161	0.0144	0.0131	1.080	2.870	0.100	1.600	0.222
156	0.0126	0.0369	0.0035	0.0239	0.0096	1.080	2.310	0.060	0.800	0.368
166	0.0668	0.0488	0.	0.0334	0.0154	1.030	1.750	0.080	0.	0.514
173	0.0933	0.1135	0.	0.0229	0.0906	1.030	0.390	0.300	0.	0.353
183	0.0794	0.0904	0.	0.0255	0.0648	0.890	0.450	0.240	0.	0.393

A_{leaf}=0.0267 B_{head}=0.0650 C_{soil}=0.8050 D=2.7777 E=0.7480

CORRELATION COEFFICIENT=0.973

MANHATTAN AGRICULTURAL EXPERIMENT

1979 WHEAT W-41
17.0 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{head}	σ_{soil}	H	MP	MS	LAI	DWT
116	0.0467	0.0692	0.0444	0.	0.0248	0.410	4.390	0.140	2.150	0.000
121	0.2128	0.1509	0.1426	0.	0.0083	0.460	3.910	0.240	5.100	0.000
128	0.3013	0.2572	0.2565	0.	0.0008	0.600	6.170	0.160	8.700	0.000
136	0.1442	0.1466	0.1393	0.	0.0073	0.710	3.800	0.200	5.000	0.000
142	0.0525	0.0718	0.0412	0.0074	0.0232	1.020	3.240	0.240	2.600	0.161
149	0.0195	0.0419	0.0170	0.0102	0.0146	1.080	2.870	0.100	1.600	0.222
156	0.0166	0.0306	0.0038	0.0169	0.0099	1.080	2.310	0.060	0.800	0.368
166	0.0525	0.0385	0.	0.0236	0.0148	1.030	1.750	0.080	0.	0.514
173	0.1581	0.0958	0.	0.0162	0.0796	1.030	0.390	0.300	0.	0.353
183	0.1151	0.0763	0.	0.0181	0.0582	0.890	0.450	0.240	0.	0.393

A_{leaf}=0.0297 B_{head}=0.0460 C_{soil}=0.5813 D=2.2233 E=0.5530

CORRELATION COEFFICIENT=0.949

1979 WHEAT W-41
35.6 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{head}	σ_{soil}	H	MP	MS	LAI	DWT
116	0.0417	0.0460	0.0285	0.	0.0175	0.410	4.390	0.140	2.150	0.000
121	0.1169	0.1361	0.1205	0.	0.0156	0.460	3.910	0.240	5.100	0.000
128	0.2399	0.2639	0.2593	0.	0.0047	0.600	6.170	0.160	8.700	0.000
136	0.1119	0.1302	0.1169	0.	0.0133	0.710	3.800	0.200	5.000	0.000
142	0.0219	0.0567	0.0324	0.0022	0.0221	1.020	3.240	0.240	2.600	0.161
149	0.0179	0.0263	0.0126	0.0031	0.0107	1.080	2.870	0.100	1.600	0.222
156	0.0091	0.0142	0.0028	0.0051	0.0063	1.080	2.310	0.060	0.800	0.368
173	0.0288	0.0435	0.	0.0049	0.0386	1.030	0.390	0.300	0.	0.353
180	0.0501	0.0442	0.	0.0046	0.0396	0.890	0.450	0.300	0.	0.332
183	0.0603	0.0347	0.	0.0054	0.0293	0.890	0.450	0.240	0.	0.393

A_{leaf}=0.0348 B_{head}=0.0138 C_{soil}=0.2023 D=1.2837 E=0.2228

CORRELATION COEFFICIENT=0.978

MANHATTAN AGRICULTURAL EXPERIMENT

1979 WHEAT W-42
8.6 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{head}	σ_{soil}	H	MP	MS	LAI	DWT
116	0.0793	0.0665	0.0588	0.	0.0077	0.340	5.590	0.200	3.000	0.000
121	0.0652	0.0756	0.0695	0.	0.0060	0.430	4.190	0.280	3.500	0.000
128	0.1429	0.1234	0.1232	0.	0.0002	0.570	3.330	0.220	6.100	0.000
136	0.0832	0.0847	0.0822	0.	0.0026	0.700	3.140	0.240	4.100	0.000
142	0.0350	0.0533	0.0177	0.0330	0.0026	0.940	2.870	0.260	3.100	0.311
149	0.0285	0.0500	0.0074	0.0390	0.0036	1.100	2.730	0.100	1.800	0.367
156	0.0429	0.0513	0.0013	0.0422	0.0079	1.060	2.080	0.060	0.600	0.397
166	0.0676	0.0642	0.	0.0452	0.0189	1.090	1.280	0.080	0.	0.426
173	0.0589	0.1035	0.	0.0648	0.0387	1.020	0.780	0.340	0.	0.610
183	0.1119	0.0979	0.	0.0606	0.0372	0.870	0.110	0.280	0.	0.571

A_{leaf}=0.0202 B_{head}=0.1062 C_{soil}=1.2897 D=3.9798 E=1.1704

CORRELATION COEFFICIENT=0.844

1979 WHEAT W-42
13.0 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{head}	σ_{soil}	H	MP	MS	LAI	DWT
116	0.0771	0.0887	0.0717	0.	0.0171	0.340	5.590	0.200	3.000	0.000
121	0.0984	0.1032	0.0867	0.	0.0165	0.430	4.190	0.280	3.500	0.000
136	0.1291	0.1135	0.1045	0.	0.0090	0.700	3.140	0.240	4.100	0.000
142	0.0575	0.0604	0.0315	0.0202	0.0087	0.940	2.870	0.260	3.100	0.311
149	0.0174	0.0442	0.0128	0.0238	0.0076	1.100	2.730	0.100	1.800	0.367
156	0.0214	0.0379	0.0019	0.0258	0.0102	1.060	2.080	0.060	0.600	0.397
173	0.0316	0.0899	0.	0.0396	0.0503	1.020	0.780	0.340	0.	0.610
183	0.0813	0.0832	0.	0.0371	0.0461	0.870	0.110	0.280	0.	0.571

A_{leaf}=0.0267 B_{head}=0.0650 C_{soil}=0.8050 D=2.7777 E=0.7480

CORRELATION COEFFICIENT=0.847

MANHATTAN AGRICULTURAL EXPERIMENT

1979 WHEAT W-42
17.0 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{head}	σ_{soil}	H	MP	MS	LAI	DWT
116	0.1279	0.0943	0.0722	0.	0.0221	0.340	5.590	0.200	3.000	0.000
121	0.1318	0.1125	0.0890	0.	0.0235	0.430	4.190	0.280	3.500	0.000
136	0.1403	0.1237	0.1092	0.	0.0145	0.700	3.140	0.240	4.100	0.000
142	0.0832	0.0658	0.0378	0.0143	0.0136	0.940	2.870	0.260	3.100	0.311
149	0.0321	0.0413	0.0149	0.0169	0.0095	1.100	2.730	0.100	1.800	0.367
156	0.0257	0.0307	0.0021	0.0183	0.0104	1.060	2.080	0.060	0.600	0.397
166	0.0302	0.0376	0.	0.0196	0.0180	1.090	1.280	0.080	0.	0.426
173	0.0661	0.0790	0.	0.0281	0.0509	1.020	0.780	0.340	0.	0.610
183	0.0955	0.0720	0.	0.0263	0.0457	0.870	0.110	0.280	0.	0.571

A_{leaf}=0.0297 B_{head}=0.0460 C_{soil}=0.5813 D=2.2233 E=0.5530

CORRELATION COEFFICIENT=0.958

1979 WHEAT W-42
35.6 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{head}	σ_{soil}	H	MP	MS	LAI	DWT
116	0.0916	0.0716	0.0509	0.	0.0207	0.340	5.590	0.200	3.000	0.000
121	0.0897	0.0920	0.0660	0.	0.0260	0.430	4.190	0.280	3.500	0.000
128	0.1679	0.1692	0.1578	0.	0.0114	0.570	3.330	0.220	6.100	0.000
136	0.0794	0.1049	0.0855	0.	0.0195	0.700	3.140	0.240	4.100	0.000
142	0.0256	0.0581	0.0361	0.0043	0.0177	0.940	2.870	0.260	3.100	0.311
149	0.0227	0.0264	0.0129	0.0051	0.0085	1.100	2.730	0.100	1.800	0.367
156	0.0138	0.0134	0.0016	0.0055	0.0064	1.060	2.080	0.060	0.600	0.397
173	0.0135	0.0398	0.	0.0084	0.0314	1.020	0.780	0.340	0.	0.610
180	0.0631	0.0339	0.	0.0100	0.0239	0.870	0.570	0.300	0.	0.725
183	0.0708	0.0351	0.	0.0079	0.0272	0.870	0.110	0.280	0.	0.571

A_{leaf}=0.0348 B_{head}=0.0138 C_{soil}=0.2023 D=1.2837 E=0.2228

CORRELATION COEFFICIENT=0.879

MANHATTAN AGRICULTURAL EXPERIMENT

1979 WHEAT W-41
8.6 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{head}	σ_{soil}	H	MP	MS	LAI	DWT
116	0.0356	0.0511	0.0212	0.	0.0299	0.410	4.390	0.140	2.150	0.000
121	0.0479	0.0686	0.0623	0.	0.0063	0.460	3.910	0.240	5.100	0.000
128	0.0923	0.1093	0.1090	0.	0.0003	0.600	6.170	0.160	8.700	0.000
136	0.0724	0.0666	0.0610	0.	0.0056	0.710	3.800	0.200	5.000	0.000
142	0.0550	0.0513	0.0159	0.0138	0.0216	1.020	3.240	0.240	2.600	0.161
149	0.0363	0.0404	0.0064	0.0190	0.0149	1.080	2.870	0.100	1.600	0.222
156	0.0204	0.0424	0.0013	0.0316	0.0096	1.080	2.310	0.060	0.800	0.368
166	0.0912	0.0579	0.	0.0441	0.0138	1.030	1.750	0.080	0.	0.514
173	0.1119	0.1197	0.	0.0303	0.0895	1.030	0.390	0.300	0.	0.353
183	0.0977	0.0962	0.	0.0337	0.0625	0.890	0.450	0.240	0.	0.393

A_{leaf}=0.0126 B_{head}=0.0858 C_{soil}=0.9868 D=3.3902 E=0.7116

CORRELATION COEFFICIENT=0.848

1979 WHEAT W-41
13.0 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{head}	σ_{soil}	H	MP	MS	LAI	DWT
116	0.0319	0.0620	0.0306	0.	0.0314	0.410	4.390	0.140	2.150	0.000
121	0.0813	0.1171	0.1036	0.	0.0135	0.460	3.910	0.240	5.100	0.000
128	0.1820	0.1929	0.1912	0.	0.0017	0.600	6.170	0.160	8.700	0.000
136	0.1021	0.1129	0.1011	0.	0.0118	0.710	3.800	0.200	5.000	0.000
142	0.0676	0.0702	0.0295	0.0094	0.0314	1.020	3.240	0.240	2.600	0.161
149	0.0407	0.0434	0.0120	0.0129	0.0184	1.080	2.870	0.100	1.600	0.222
156	0.0158	0.0360	0.0026	0.0214	0.0119	1.080	2.310	0.060	0.800	0.368
166	0.0374	0.0471	0.	0.0299	0.0172	1.030	1.750	0.080	0.	0.514
173	0.0676	0.1103	0.	0.0206	0.0897	1.030	0.390	0.300	0.	0.353
183	0.0955	0.0890	0.	0.0229	0.0661	0.890	0.450	0.240	0.	0.393

A_{leaf}=0.0224 B_{head}=0.0582 C_{soil}=0.6167 D=2.0508 E=0.4699

CORRELATION COEFFICIENT=0.944

MANHATTAN AGRICULTURAL EXPERIMENT

1979 WHEAT W-41
17.0 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{head}	σ_{soil}	H	MP	MS	LAI	DWT
116	0.0468	0.0599	0.0311	0.	0.0289	0.410	4.390	0.140	2.150	0.000
121	0.1820	0.1322	0.1150	0.	0.0172	0.460	3.910	0.240	5.100	0.000
128	0.2673	0.2265	0.2234	0.	0.0031	0.600	6.170	0.160	8.700	0.000
136	0.1795	0.1268	0.1120	0.	0.0148	0.710	3.800	0.200	5.000	0.000
142	0.0975	0.0744	0.0336	0.0073	0.0335	1.020	3.240	0.240	2.600	0.161
149	0.0468	0.0421	0.0137	0.0101	0.0183	1.080	2.870	0.100	1.600	0.222
156	0.0309	0.0318	0.0032	0.0168	0.0119	1.080	2.310	0.060	0.800	0.368
166	0.0380	0.0405	0.	0.0234	0.0171	1.030	1.750	0.080	0.	0.514
173	0.0891	0.0968	0.	0.0161	0.0807	1.030	0.390	0.300	0.	0.353
183	0.1409	0.0789	0.	0.0179	0.0610	0.890	0.450	0.240	0.	0.393

A_{leaf}=0.0269 B_{head}=0.0456 C_{soil}=0.4465 D=1.4348 E=0.3590

CORRELATION COEFFICIENT=0.956

1979 WHEAT W-41
35.6 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{head}	σ_{soil}	H	MP	MS	LAI	DWT
116	0.0316	0.0380	0.0227	0.	0.0153	0.410	4.390	0.140	2.150	0.000
121	0.1050	0.1180	0.1021	0.	0.0159	0.460	3.910	0.240	5.100	0.000
128	0.1820	0.2376	0.2319	0.	0.0057	0.600	6.170	0.160	8.700	0.000
136	0.1050	0.1123	0.0989	0.	0.0134	0.710	3.800	0.200	5.000	0.000
142	0.0335	0.0568	0.0301	0.0039	0.0228	1.020	3.240	0.240	2.600	0.161
149	0.0243	0.0284	0.0121	0.0053	0.0110	1.080	2.870	0.100	1.600	0.222
156	0.0095	0.0190	0.0030	0.0089	0.0071	1.080	2.310	0.060	0.800	0.368
173	0.0372	0.0497	0.	0.0085	0.0412	1.030	0.390	0.300	0.	0.353
180	0.0537	0.0495	0.	0.0080	0.0415	0.890	0.450	0.300	0.	0.332
183	0.0427	0.0419	0.	0.0095	0.0324	0.890	0.450	0.240	0.	0.393

A_{leaf}=0.0345 B_{head}=0.0241 C_{soil}=0.1574 D=0.3888 E=0.1701

CORRELATION COEFFICIENT=0.984

2

MANHATTAN AGRICULTURAL EXPERIMENT

1979 WHEAT W-42
8.6 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{head}	σ_{soil}	H	MP	MS	LAI	DWT
116	0.0592	0.0566	0.0332	0.	0.0233	0.340	5.590	0.200	3.000	0.000
121	0.0571	0.0632	0.0403	0.	0.0229	0.430	4.190	0.280	3.500	0.000
128	0.0875	0.0784	0.0756	0.	0.0028	0.570	3.330	0.220	6.100	0.000
136	0.0887	0.0615	0.0487	0.	0.0128	0.700	3.140	0.240	4.100	0.000
142	0.0479	0.0486	0.0121	0.0257	0.0098	0.940	2.870	0.260	3.100	0.311
149	0.0355	0.0441	0.0047	0.0315	0.0079	1.100	2.730	0.100	1.800	0.367
156	0.0324	0.0448	0.0007	0.0340	0.0101	1.060	2.080	0.060	0.600	0.397
166	0.0575	0.0552	0.	0.0365	0.0186	1.090	1.280	0.080	0.	0.426
173	0.1000	0.0947	0.	0.0523	0.0424	1.020	0.780	0.340	0.	0.610
183	0.0871	0.0888	0.	0.0490	0.0399	0.870	0.110	0.280	0.	0.571

A_{leaf}=0.0126 B_{head}=0.0858 C_{soil}=0.9868 D=3.3902 E=0.7116

CORRELATION COEFFICIENT=0.899

1979 WHEAT W-42
13.0 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{head}	σ_{soil}	H	MP	MS	LAI	DWT
116	0.0608	0.0808	0.0507	0.	0.0301	0.340	5.590	0.200	3.000	0.000
121	0.0676	0.0965	0.0631	0.	0.0333	0.430	4.190	0.280	3.500	0.000
136	0.1099	0.0999	0.0783	0.	0.0216	0.700	3.140	0.240	4.100	0.000
142	0.0708	0.0659	0.0281	0.0181	0.0197	0.940	2.870	0.260	3.100	0.311
149	0.0282	0.0447	0.0108	0.0214	0.0125	1.100	2.730	0.100	1.800	0.367
156	0.0324	0.0369	0.0015	0.0231	0.0124	1.060	2.080	0.060	0.600	0.397
173	0.0603	0.0955	0.	0.0355	0.0600	1.020	0.780	0.340	0.	0.610
183	0.0832	0.0868	0.	0.0332	0.0535	0.870	0.110	0.280	0.	0.571

A_{leaf}=0.0224 B_{head}=0.0582 C_{soil}=0.6167 D=2.0508 E=0.4699

CORRELATION COEFFICIENT=0.801

MANHATTAN AGRICULTURAL EXPERIMENT

1979 WHEAT W-42
17.0 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{head}	σ_{soil}	H	MP	MS	LAI	DWT
116	0.1143	0.0836	0.0531	0.	0.0304	0.340	5.590	0.200	3.000	0.000
121	0.1014	0.1028	0.0672	0.	0.0356	0.430	4.190	0.280	3.500	0.000
136	0.1445	0.1094	0.0848	0.	0.0246	0.700	3.140	0.240	4.100	0.000
142	0.1208	0.0744	0.0358	0.0142	0.0244	0.940	2.870	0.260	3.100	0.311
149	0.0513	0.0441	0.0136	0.0167	0.0138	1.100	2.730	0.100	1.800	0.367
156	0.0513	0.0321	0.0018	0.0181	0.0122	1.060	2.080	0.060	0.600	0.397
166	0.0324	0.0388	0.	0.0194	0.0194	1.090	1.280	0.080	0.	0.426
173	0.1000	0.0911	0.	0.0278	0.0633	1.020	0.780	0.340	0.	0.610
183	0.1380	0.0811	0.	0.0260	0.0551	0.870	0.110	0.280	0.	0.571

A_{leaf}=0.0269 B_{head}=0.0456 C_{soil}=0.4465 D=1.4348 E=0.3590

CORRELATION COEFFICIENT=0.857

1979 WHEAT W-42
35.6 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{head}	σ_{soil}	H	MP	MS	LAI	DWT
116	0.0773	0.0603	0.0414	0.	0.0189	0.340	5.590	0.200	3.000	0.000
121	0.1057	0.0785	0.0542	0.	0.0243	0.430	4.190	0.280	3.500	0.000
128	0.1390	0.1482	0.1359	0.	0.0123	0.570	3.330	0.220	6.100	0.000
136	0.0887	0.0899	0.0711	0.	0.0188	0.700	3.140	0.240	4.100	0.000
142	0.0401	0.0677	0.0389	0.0075	0.0214	0.940	2.870	0.260	3.100	0.311
149	0.0385	0.0331	0.0142	0.0088	0.0100	1.100	2.730	0.100	1.800	0.367
156	0.0219	0.0186	0.0017	0.0096	0.0073	1.060	2.080	0.060	0.600	0.397
173	0.0224	0.0569	0.	0.0147	0.0422	1.020	0.780	0.340	0.	0.610
180	0.0550	0.0531	0.	0.0175	0.0356	0.870	0.570	0.300	0.	0.725
183	0.0589	0.0491	0.	0.0137	0.0353	0.870	0.110	0.280	0.	0.571

A_{leaf}=0.0345 B_{head}=0.0241 C_{soil}=0.1574 D=0.3888 E=0.1701

CORRELATION COEFFICIENT=0.870

APPENDIX B - 1979 Sorghum Data

Observed values of the backscattering coefficients, predicted values, ground-truth values, and correlation between predicted and observed backscattering coefficients, and model values for six sorghum fields.

MODEL EQUATION

$$\sigma^{o}_{pred} = \sigma^{o}_{leaf} + \sigma^{o}_{stalk} + \sigma^{o}_{soil}$$

$$= A_{leaf}\,(1 - e^{-E \cdot LAI})$$

$$+ \frac{B_{stalk} \cdot W \cdot H}{E \cdot LAI}\,(1 - e^{-E \cdot LAI})$$

$$+ C_{soil} \cdot m_s \cdot e^{-D \cdot W \cdot H}\, e^{E \cdot LAI}$$

Symbol	SI Units	Description
σ^{o}_{pred}	$m^2\ m^{-2}$	Predicted backscattering cross section coefficient
σ^{o}_{leaf}	$m^2\ m^{-2}$	Backscattering cross section coefficient for leaf contribution
σ^{o}_{stalk}	$m^2\ m^{-2}$	Backscattering cross section coefficient for stalk contribution
σ^{o}_{soil}	$m^2\ m^{-2}$	Backscattering cross section coefficient for soil contribution
LAI	$m^2\ m^{-2}$	Leaf Area Index
H	m	crop canopy height
W	$kg\ m^{-3}$	Volumetric normalized plant water content
m_s	$kg\ m^{-3}$	Volumetric soil moisture content
A_{leaf}	----	Empirical coefficient for leaf contribution to predicted radar backscatter
B_{stalk}	----	Empirical coefficient for stalk contribution to predicted radar backscatter
C_{soil}	----	Empirical coefficient for soil contribution to predicted radar backscatter
D	nepers $m\ kg^{-1}$	Empirical attenuation coefficient for attenuation due to plant water
E	nepers	Empirical attenuation constant for attenuation due to leaves
ρ	----	Correlation coefficient between predicted and observed backscatter coefficients

MANHATTAN AGRICULTURAL EXPERIMENT

1979 SORGHUM S-31
8.6 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
156	0.0771	0.0877	0.0632	0.0007	0.0239	0.150	0.327	0.070	0.600	0.070
169	0.1028	0.1277	0.1038	0.0081	0.0157	0.430	1.630	0.140	1.200	0.096
177	0.1718	0.1755	0.1647	0.0078	0.0030	0.510	2.500	0.280	3.600	0.361
191	0.1660	0.1870	0.1740	0.0129	0.0002	0.800	3.730	0.320	5.400	0.557
200	0.1923	0.1882	0.1758	0.0123	0.	0.950	3.580	0.320	6.500	0.668
204	0.2466	0.1904	0.1758	0.0146	0.	1.080	3.700	0.280	6.450	0.823
207	0.2234	0.1917	0.1759	0.0157	0.	1.180	3.730	0.280	6.600	0.939
208	0.2089	0.1922	0.1760	0.0162	0.	1.190	3.870	0.280	6.700	0.978
212	0.1862	0.1955	0.1752	0.0203	0.	1.260	4.130	0.220	6.000	1.133
242	0.1660	0.1860	0.1679	0.0178	0.0002	1.270	2.500	0.200	4.000	1.850

A_{leaf}=0.1773 B_{stalk}=0.0174 C_{soil}=0.5575 D=1.0304 E=0.7339

CORRELATION COEFFICIENT=0.885

1979 SORGHUM S-31
13.0 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
156	0.0973	0.0875	0.0551	0.0016	0.0308	0.150	0.327	0.070	0.600	0.070
169	0.1309	0.1231	0.0899	0.0190	0.0143	0.430	1.630	0.140	1.200	0.096
177	0.1135	0.1603	0.1405	0.0180	0.0019	0.510	2.500	0.280	3.600	0.361
191	0.1762	0.1772	0.1477	0.0295	0.	0.800	3.730	0.320	5.400	0.557
200	0.1742	0.1773	0.1491	0.0282	0.	0.950	3.580	0.320	6.500	0.668
204	0.2143	0.1824	0.1491	0.0333	0.	1.080	3.700	0.280	6.450	0.823
207	0.1941	0.1851	0.1492	0.0359	0.	1.180	3.730	0.280	6.600	0.939
208	0.2163	0.1863	0.1493	0.0370	0.	1.190	3.870	0.280	6.700	0.978
212	0.2042	0.1952	0.1486	0.0465	0.	1.260	4.130	0.220	6.000	1.133
242	0.1820	0.1841	0.1430	0.0410	0.0001	1.270	2.500	0.200	4.000	1.850

A_{leaf}=0.1502 B_{stalk}=0.0413 C_{soil}=0.7500 D=1.5460 E=0.7611

CORRELATION COEFFICIENT=0.859

MANHATTAN AGRICULTURAL EXPERIMENT

1979 SORGHUM S-31
17.0 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
156	0.1099	0.0898	0.0490	0.0003	0.0405	0.150	0.327	0.070	0.600	0.070
169	0.1510	0.1405	0.0876	0.0038	0.0492	0.430	1.630	0.140	1.200	0.096
177	0.1660	0.2099	0.1754	0.0046	0.0300	0.510	2.500	0.280	3.600	0.361
191	0.2449	0.2200	0.2033	0.0082	0.0085	0.800	3.730	0.320	5.400	0.557
200	0.2612	0.2255	0.2127	0.0082	0.0046	0.950	3.580	0.320	6.500	0.668
204	0.2661	0.2253	0.2124	0.0096	0.0033	1.080	3.700	0.280	6.450	0.823
207	0.2559	0.2264	0.2134	0.0104	0.0026	1.180	3.730	0.280	6.600	0.939
208	0.2291	0.2271	0.2140	0.0108	0.0023	1.190	3.870	0.280	6.700	0.978
212	0.2275	0.2241	0.2089	0.0133	0.0019	1.260	4.130	0.220	6.000	1.133
242	0.1549	0.2027	0.1834	0.0107	0.0086	1.270	2.500	0.200	4.000	1.850

A_{leaf}=0.2298 B_{stalk}=0.0067 C_{soil}=0.7500 D=0.3969 E=0.4000

CORRELATION COEFFICIENT=0.833

1979 SORGHUM S-31
35.6 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
156	0.0455	0.0792	0.0397	0.0013	0.0382	0.150	0.327	0.070	0.600	0.070
169		0.1088	0.0709	0.0164	0.0215	0.430	1.630	0.140	1.200	0.096
177	0.1259	0.1684	0.1419	0.0200	0.0066	0.510	2.500	0.280	3.600	0.361
191	0.2404	0.2008	0.1645	0.0361	0.0002	0.800	3.730	0.320	5.400	0.557
200	0.2618	0.2080	0.1721	0.0358	0.0001	0.950	3.580	0.320	6.500	0.668
204	0.2193	0.2141	0.1718	0.0423	0.	1.080	3.700	0.280	6.450	0.823
207	0.2404	0.2184	0.1726	0.0457	0.	1.180	3.730	0.280	6.600	0.939
208	0.2399	0.2205	0.1732	0.0473	0.	1.190	3.870	0.280	6.700	0.978
212	0.2692	0.2273	0.1690	0.0582	0.	1.260	4.130	0.220	6.000	1.133
242	0.2000	0.1954	0.1484	0.0468	0.0002	1.270	2.500	0.200	4.000	1.850

A_{leaf}=0.1859 B_{stalk}=0.0295 C_{soil}=0.7500 D=1.5810 E=0.4000

CORRELATION COEFFICIENT=0.944

MANHATTAN AGRICULTURAL EXPERIMENT

1979 SORGHUM S-32
8.6 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
169	0.1200	0.1320	0.1090	0.0068	0.0162	0.430	1.400	0.140	1.300	0.096
177	0.1507	0.1687	0.1546	0.0080	0.0061	0.510	2.120	0.260	2.800	0.214
191	0.1660	0.1834	0.1717	0.0113	0.0005	0.800	2.880	0.280	4.700	0.400
200	0.2042	0.1903	0.1744	0.0159	0.0001	0.950	4.000	0.300	5.600	0.785
212	0.1690	0.1962	0.1761	0.0201	0.	1.260	4.600	0.240	6.800	1.298
242	0.1862	0.1792	0.1616	0.0171	0.0005	1.270	2.050	0.160	3.300	2.155

A_{leaf}=0.1773 B_{stalk}=0.0174 C_{soil}=0.5575 D=1.0304 E=0.7339

CORRELATION COEFFICIENT=0.838

1979 SORGHUM S-32
13.0 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
169	0.1057	0.1255	0.0943	0.0158	0.0154	0.430	1.400	0.140	1.300	0.096
177	0.1239	0.1551	0.1323	0.0185	0.0044	0.510	2.120	0.260	2.800	0.214
191	0.1803	0.1720	0.1460	0.0258	0.0002	0.800	2.880	0.280	4.700	0.400
200	0.1910	0.1843	0.1481	0.0363	0.	0.950	4.000	0.300	5.600	0.785
212	0.1995	0.1953	0.1493	0.0460	0.	1.260	4.600	0.240	6.800	1.298
242	0.1910	0.1775	0.1380	0.0393	0.0002	1.270	2.050	0.160	3.300	2.155

A_{leaf}=0.1502 B_{stalk}=0.0413 C_{soil}=0.7500 D=1.5460 E=0.7611

CORRELATION COEFFICIENT=0.951

MANHATTAN AGRICULTURAL EXPERIMENT

1979 SORGHUM S-32
17.0 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
169	0.1069	0.1455	0.0932	0.0032	0.0492	0.430	1.400	0.140	1.300	0.096
177	0.1622	0.2006	0.1548	0.0044	0.0414	0.510	2.120	0.260	2.800	0.214
191	0.2089	0.2146	0.1947	0.0070	0.0128	0.800	2.880	0.280	4.700	0.400
200	0.2410	0.2208	0.2053	0.0102	0.0053	0.950	4.000	0.300	5.600	0.785
212	0.2213	0.2293	0.2147	0.0134	0.0012	1.260	4.600	0.240	6.800	1.298
242	0.1622	0.1896	0.1684	0.0097	0.0114	1.270	2.050	0.160	3.300	2.155

A_{leaf}=0.2298 B_{stalk}=0.0067 C_{soil}=0.7500 D=0.3969 E=0.4000

CORRELATION COEFFICIENT=0.946

1979 SORGHUM S-32
35.6 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
169		0.1133	0.0754	0.0139	0.0241	0.430	1.400	0.140	1.300	0.096
177	0.1910	0.1560	0.1253	0.0192	0.0115	0.510	2.120	0.260	2.800	0.214
191	0.2449	0.1891	0.1575	0.0307	0.0008	0.800	2.880	0.280	4.700	0.400
200	0.2582	0.2110	0.1661	0.0448	0.0001	0.950	4.000	0.300	5.600	0.785
212	0.2541	0.2325	0.1737	0.0588	0.	1.260	4.600	0.240	6.800	1.298
242	0.1742	0.1795	0.1362	0.0427	0.0005	1.270	2.050	0.160	3.300	2.155

A_{leaf}=0.1859 B_{stalk}=0.0295 C_{soil}=0.7500 D=1.5810 E=0.4000

CORRELATION COEFFICIENT=0.789

MANHATTAN AGRICULTURAL EXPERIMENT

1979 SORGHUM S-33
8.6 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
169	0.1151	0.0840	0.0545	0.0088	0.0208	0.430	1.400	0.100	0.500	0.085
177	0.1422	0.1364	0.1090	0.0193	0.0080	0.510	3.369	0.220	1.300	0.251
191	0.1683	0.1912	0.1744	0.0167	0.	0.800	5.000	0.300	5.600	0.636
200	0.1879	0.1900	0.1744	0.0156	0.0001	0.950	3.929	0.280	5.600	0.817
212	0.1702	0.1927	0.1744	0.0182	0.	1.260	3.465	0.220	5.600	1.058
247	0.2138	0.1768	0.1637	0.0125	0.0005	1.270	1.570	0.100	3.500	1.762

A_{leaf}=0.1773 B_{stalk}=0.0174 C_{soil}=0.5575 D=1.0304 E=0.7339

CORRELATION COEFFICIENT=0.810

1979 SORGHUM S-33
13.0 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
169	0.1208	0.0884	0.0475	0.0207	0.0202	0.430	1.400	0.100	0.500	0.085
177	0.1380	0.1437	0.0943	0.0450	0.0043	0.510	3.369	0.220	1.300	0.251
191	0.1660	0.1862	0.1481	0.0382	0.	0.800	5.000	0.300	5.600	0.636
200	0.1581	0.1837	0.1481	0.0356	0.	0.950	3.929	0.280	5.600	0.817
212	0.1871	0.1897	0.1481	0.0417	0.	1.260	3.465	0.220	5.600	1.058
247	0.1820	0.1687	0.1397	0.0287	0.0002	1.270	1.570	0.100	3.500	1.762

A_{leaf}=0.1502 B_{stalk}=0.0413 C_{soil}=0.7500 D=1.5460 E=0.7611

CORRELATION COEFFICIENT=0.858

MANHATTAN AGRICULTURAL EXPERIMENT

1979 SORGHUM S-33
17.0 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
169	0.1069	0.0937	0.0417	0.0037	0.0484	0.430	1.400	0.100	0.500	0.085
177	0.1503	0.1518	0.0932	0.0090	0.0496	0.510	3.369	0.220	1.300	0.251
191	0.2301	0.2210	0.2053	0.0108	0.0049	0.800	5.000	0.300	5.600	0.636
200	0.2535	0.2204	0.2053	0.0100	0.0051	0.950	3.929	0.280	5.600	0.817
212	0.2239	0.2202	0.2053	0.0117	0.0031	1.260	3.465	0.220	5.600	1.058
247	0.1380	0.1887	0.1731	0.0072	0.0084	1.270	1.570	0.100	3.500	1.762

A_{leaf}=0.2298 B_{stalk}=0.0067 C_{soil}=0.7500 D=0.3969 E=0.4000

CORRELATION COEFFICIENT=0.883

1979 SORGHUM S-33
35.6 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
169		0.0735	0.0337	0.0161	0.0237	0.430	1.400	0.100	0.500	0.085
177	0.0977	0.1214	0.0754	0.0396	0.0065	0.510	3.369	0.220	1.300	0.251
191	0.1910	0.2133	0.1661	0.0471	0.	0.800	5.000	0.300	5.600	0.636
200	0.2280	0.2102	0.1661	0.0440	0.0001	0.950	3.929	0.280	5.600	0.817
212	0.2042	0.2176	0.1661	0.0514	0.	1.260	3.465	0.220	5.600	1.058
247	0.1259	0.1726	0.1401	0.0317	0.0008	1.270	1.570	0.100	3.500	1.762

A_{leaf}=0.1859 B_{stalk}=0.0295 C_{soil}=0.7500 D=1.5810 E=0.4000

CORRELATION COEFFICIENT=0.924

MANHATTAN AGRICULTURAL EXPERIMENT

1979 SORGHUM S-34
8.6 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
171	0.1099	0.1312	0.1139	0.0076	0.0097	0.500	1.400	0.100	1.400	0.106
178	0.1875	0.1723	0.1567	0.0130	0.0031	0.600	3.000	0.300	2.900	0.386
192	0.1950	0.1862	0.1724	0.0136	0.0003	0.820	3.500	0.320	4.889	0.758
201	0.2113	0.1909	0.1737	0.0171	0.0001	1.000	3.900	0.300	5.300	1.135
213	0.1820	0.1938	0.1761	0.0177	0.	1.270	4.020	0.200	6.800	1.512
247	0.1820	0.1748	0.1616	0.0125	0.0007	1.270	1.500	0.100	3.300	1.832

A_{leaf}=0.1773 B_{stalk}=0.0174 C_{soil}=0.5575 D=1.0304 E=0.7339

CORRELATION COEFFICIENT=0.927

1979 SORGHUM S-34
13.0 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
171	0.1151	0.1250	0.0984	0.0178	0.0088	0.500	1.400	0.100	1.400	0.106
178	0.1435	0.1651	0.1337	0.0300	0.0015	0.600	3.000	0.300	2.900	0.386
192	0.1910	0.1777	0.1465	0.0311	0.0001	0.820	3.500	0.320	4.889	0.758
201	0.1758	0.1867	0.1475	0.0392	0.	1.000	3.900	0.300	5.300	1.135
213	0.1754	0.1898	0.1493	0.0405	0.	1.270	4.020	0.200	6.800	1.512
247	0.1820	0.1671	0.1380	0.0288	0.0003	1.270	1.500	0.100	3.300	1.832

A_{leaf}=0.1502 B_{stalk}=0.0413 C_{soil}=0.7500 D=1.5460 E=0.7611

CORRELATION COEFFICIENT=0.849

MANHATTAN AGRICULTURAL EXPERIMENT

1979 SORGHUM S-34
17.0 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
171	0.1600	0.1346	0.0985	0.0036	0.0324	0.500	1.400	0.100	1.400	0.106
178	0.2051	0.1995	0.1578	0.0072	0.0345	0.600	3.000	0.300	2.900	0.386
192	0.2350	0.2166	0.1973	0.0085	0.0109	0.820	3.500	0.320	4.889	0.758
201	0.2361	0.2189	0.2022	0.0109	0.0057	1.000	3.900	0.300	5.300	1.135
213	0.2089	0.2278	0.2147	0.0118	0.0013	1.270	4.020	0.200	6.800	1.512
247	0.1742	0.1849	0.1684	0.0071	0.0094	1.270	1.500	0.100	3.300	1.832

A_{leaf}=0.2298 B_{stalk}=0.0067 C_{soil}=0.7500 D=0.3969 E=0.4000

CORRELATION COEFFICIENT=0.869

1979 SORGHUM S-34
35.6 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
171	0.1259	0.1097	0.0797	0.0158	0.0142	0.500	1.400	0.100	1.400	0.106
178	0.1324	0.1632	0.1276	0.0315	0.0041	0.600	3.000	0.300	2.900	0.386
192	0.1596	0.1972	0.1596	0.0372	0.0004	0.820	3.500	0.320	4.889	0.758
201	0.2312	0.2115	0.1636	0.0478	0.0001	1.000	3.900	0.300	5.300	1.135
213	0.2213	0.2255	0.1737	0.0518	0.	1.270	4.020	0.200	6.800	1.512
247	0.1180	0.1685	0.1362	0.0312	0.0010	1.270	1.500	0.100	3.300	1.832

A_{leaf}=0.1859 B_{stalk}=0.0295 C_{soil}=0.7500 D=1.5810 E=0.4000

CORRELATION COEFFICIENT=0.808

MANHATTAN AGRICULTURAL EXPERIMENT

1979 SORGHUM S-35
8.6 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
171	0.1130	0.1176	0.0922	0.0062	0.0192	0.500	1.000	0.120	1.000	0.079
178	0.1449	0.1715	0.1604	0.0074	0.0038	0.600	1.830	0.220	3.200	0.325
192	0.1910	0.1838	0.1728	0.0106	0.0004	0.820	2.800	0.300	5.000	0.476
201	0.1862	0.1889	0.1758	0.0130	0.	1.000	3.600	0.320	6.500	1.074
213	0.1742	0.1945	0.1761	0.0184	0.	1.270	4.170	0.200	6.800	1.871
254	0.2042	0.1690	0.1529	0.0129	0.0032	1.270	1.340	0.240	2.700	2.400

A_{leaf}=0.1773 B_{stalk}=0.0174 C_{soil}=0.5575 D=1.0304 E=0.7339

CORRELATION COEFFICIENT=0.764

1979 SORGHUM S-35
13.0 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
171	0.1052	0.1139	0.0800	0.0144	0.0194	0.500	1.000	0.120	1.000	0.079
178	0.1472	0.1566	0.1370	0.0170	0.0026	0.600	1.830	0.220	3.200	0.325
192	0.1862	0.1713	0.1468	0.0243	0.0001	0.820	2.800	0.300	5.000	0.476
201	0.2018	0.1789	0.1491	0.0298	0.	1.000	3.600	0.320	6.500	1.074
213	0.1862	0.1913	0.1493	0.0420	0.	1.270	4.170	0.200	6.800	1.871
254	0.2138	0.1624	0.1309	0.0298	0.0017	1.270	1.340	0.240	2.700	2.400

A_{leaf}=0.1502 B_{stalk}=0.0413 C_{soil}=0.7500 D=1.5460 E=0.7611

CORRELATION COEFFICIENT=0.820

MANHATTAN AGRICULTURAL EXPERIMENT

1979 SORGHUM S-35
17.0 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
171	0.1200	0.1280	0.0758	0.0028	0.0495	0.500	1.000	0.120	1.000	0.079
178	0.2000	0.1997	0.1659	0.0042	0.0297	0.600	1.830	0.220	3.200	0.325
192	0.2109	0.2176	0.1987	0.0067	0.0122	0.820	2.800	0.300	5.000	0.476
201	0.2594	0.2256	0.2127	0.0086	0.0043	1.000	3.600	0.320	6.500	1.074
213	0.1936	0.2281	0.2147	0.0123	0.0012	1.270	4.170	0.200	6.800	1.871
254	0.1862	0.1899	0.1518	0.0070	0.0311	1.270	1.340	0.240	2.700	2.400

A_{leaf}=0.2298 B_{stalk}=0.0067 C_{soil}=0.7500 D=0.3969 E=0.4000

CORRELATION COEFFICIENT=0.875

1979 SORGHUM S-35
35.6 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
171	0.1094	0.1008	0.0613	0.0122	0.0274	0.500	1.000	0.120	1.000	0.079
178	0.1538	0.1606	0.1342	0.0183	0.0081	0.600	1.830	0.220	3.200	0.325
192	0.1633	0.1909	0.1608	0.0293	0.0008	0.820	2.800	0.300	5.000	0.476
201	0.2148	0.2100	0.1721	0.0379	0.0001	1.000	3.600	0.320	6.500	1.074
213	0.2291	0.2274	0.1737	0.0537	0.	1.270	4.170	0.200	6.800	1.871
254	0.1349	0.1577	0.1228	0.0307	0.0041	1.270	1.340	0.240	2.700	2.400

A_{leaf}=0.1859 B_{stalk}=0.0295 C_{soil}=0.7500 D=1.5810 E=0.4000

CORRELATION COEFFICIENT=0.946

MANHATTAN AGRICULTURAL EXPERIMENT

1979 SORGHUM S-36
8.6 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
171	0.1019	0.0842	0.0451	0.0060	0.0330	0.500	0.800	0.120	0.400	0.066
178	0.1259	0.1395	0.1090	0.0214	0.0091	0.600	3.170	0.300	1.300	0.249
192	0.1660	0.1907	0.1721	0.0185	0.0001	0.820	4.700	0.300	4.800	0.587
201	0.1995	0.1939	0.1752	0.0188	0.	1.000	4.800	0.340	6.000	1.352
213	0.1778	0.1963	0.1752	0.0211	0.	1.270	4.250	0.200	6.000	1.562
254	0.2234	0.1824	0.1656	0.0162	0.0005	1.270	2.130	0.240	3.700	2.489

A_{leaf}=0.1773 B_{stalk}=0.0174 C_{soil}=0.5575 D=1.0304 E=0.7339

CORRELATION COEFFICIENT=0.844

1979 SORGHUM S-36
13.0 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
171	0.1035	0.0894	0.0394	0.0142	0.0358	0.500	0.800	0.120	0.400	0.066
178	0.1288	0.1486	0.0943	0.0498	0.0044	0.600	3.170	0.300	1.300	0.249
192	0.1510	0.1887	0.1463	0.0424	0.	0.820	4.700	0.300	4.800	0.587
201	0.1799	0.1915	0.1486	0.0429	0.	1.000	4.800	0.340	6.000	1.352
213	0.1742	0.1969	0.1486	0.0483	0.	1.270	4.250	0.200	6.000	1.562
254	0.2208	0.1786	0.1412	0.0373	0.0002	1.270	2.130	0.240	3.700	2.489

A_{leaf}=0.1502 B_{stalk}=0.0413 C_{soil}=0.7500 D=1.5460 E=0.7611

CORRELATION COEFFICIENT=0.751

MANHATTAN AGRICULTURAL EXPERIMENT

1979 SORGHUM S-36
17.0 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
171	0.1321	0.1019	0.0340	0.0025	0.0654	0.500	0.800	0.120	0.400	0.066
178	0.1858	0.1661	0.0932	0.0100	0.0629	0.600	3.170	0.300	1.300	0.249
192	0.2109	0.2148	0.1961	0.0115	0.0071	0.820	4.700	0.300	4.800	0.587
201	0.2512	0.2246	0.2089	0.0123	0.0034	1.000	4.800	0.340	6.000	1.352
213	0.1832	0.2243	0.2089	0.0138	0.0016	1.270	4.250	0.200	6.000	1.562
254	0.1820	0.2010	0.1775	0.0095	0.0140	1.270	2.130	0.240	3.700	2.489

A_{leaf}=0.2298 B_{stalk}=0.0067 C_{soil}=0.7500 D=0.3969 E=0.4000

CORRELATION COEFFICIENT=0.804

1979 SORGHUM S-36
35.6 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
171	0.1064	0.0792	0.0275	0.0109	0.0407	0.500	0.800	0.120	0.400	0.066
178	0.1371	0.1258	0.0754	0.0438	0.0066	0.600	3.170	0.300	1.300	0.249
192	0.1675	0.2093	0.1587	0.0506	0.0001	0.820	4.700	0.300	4.800	0.587
201	0.1932	0.2228	0.1690	0.0537	0.	1.000	4.800	0.340	6.000	1.352
213	0.2173	0.2295	0.1690	0.0604	0.	1.270	4.250	0.200	6.000	1.562
254	0.1479	0.1859	0.1436	0.0417	0.0006	1.270	2.130	0.240	3.700	2.489

A_{leaf}=0.1859 B_{stalk}=0.0295 C_{soil}=0.7500 D=1.5810 E=0.4000

CORRELATION COEFFICIENT=0.922

MANHATTAN AGRICULTURAL EXPERIMENT

1979 SORGHUM S-31
8.6 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
156	0.0738	0.0750	0.0370	0.0014	0.0366	0.150	0.327	0.070	0.600	0.070
169	0.0933	0.1067	0.0643	0.0171	0.0253	0.430	1.630	0.140	1.200	0.096
177	0.1321	0.1452	0.1184	0.0191	0.0077	0.510	2.500	0.280	3.600	0.361
191	0.1791	0.1658	0.1321	0.0332	0.0005	0.800	3.730	0.320	5.400	0.557
200	0.1862	0.1686	0.1360	0.0324	0.0002	0.950	3.580	0.320	6.500	0.668
204	0.1959	0.1743	0.1359	0.0383	0.0001	1.080	3.700	0.280	6.450	0.823
207	0.2085	0.1777	0.1363	0.0414	0.	1.180	3.730	0.280	6.600	0.939
208	0.1730	0.1793	0.1366	0.0427	0.	1.190	3.870	0.280	6.700	0.978
212	0.1778	0.1876	0.1345	0.0531	0.	1.260	4.130	0.220	6.000	1.133
242	0.1778	0.1674	0.1226	0.0443	0.0005	1.270	2.500	0.200	4.000	1.850

A_{leaf}=0.1413 B_{stalk}=0.0325 C_{soil}=0.7500 D=1.1640 E=0.5055

CORRELATION COEFFICIENT=0.946

1979 SORGHUM S-31
13.0 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
156	0.0631	0.0747	0.0574	0.0004	0.0169	0.150	0.327	0.070	0.600	0.070
169	0.1183	0.1061	0.0929	0.0046	0.0086	0.430	1.630	0.140	1.200	0.096
177	0.1256	0.1476	0.1422	0.0043	0.0011	0.510	2.500	0.280	3.600	0.361
191	0.1507	0.1557	0.1486	0.0070	0.	0.800	3.730	0.320	5.400	0.557
200	0.1585	0.1565	0.1498	0.0067	0.	0.950	3.580	0.320	6.500	0.668
204	0.1730	0.1577	0.1498	0.0079	0.	1.080	3.700	0.280	6.450	0.823
207	0.1803	0.1584	0.1499	0.0085	0.	1.180	3.730	0.280	6.600	0.939
208	0.1791	0.1587	0.1499	0.0088	0.	1.190	3.870	0.280	6.700	0.978
212	0.1449	0.1604	0.1494	0.0110	0.	1.260	4.130	0.220	6.000	1.133
242	0.1581	0.1543	0.1445	0.0097	0.	1.270	2.500	0.200	4.000	1.850

A_{leaf}=0.1507 B_{stalk}=0.0102 C_{soil}=0.4177 D=1.3710 E=0.7990

CORRELATION COEFFICIENT=0.906

MANHATTAN AGRICULTURAL EXPERIMENT

1979 SORGHUM S-31
17.0 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
156	0.0951	0.0831	0.0424	0.0003	0.0[illegible]4	0.150	0.327	0.070	0.600	0.070
169	0.1409	0.1271	0.0758	0.0043	0.0470	0.430	1.630	0.140	1.200	0.096
177	0.1738	0.1846	0.1518	0.0052	0.0276	0.510	2.500	0.280	3.600	0.361
191	0.1862	0.1923	0.1760	0.0094	0.0070	0.800	3.730	0.320	5.400	0.557
200	0.2193	0.1972	0.1841	0.0093	0.0037	0.950	3.580	0.320	6.500	0.668
204	0.2371	0.1974	0.1838	0.0110	0.0025	1.080	3.700	0.280	6.450	0.823
207	0.2404	0.1986	0.1847	0.0119	0.0020	1.180	3.730	0.280	6.600	0.939
208	0.2280	0.1993	0.1853	0.0123	0.0017	1.190	3.870	0.280	6.700	0.978
212	0.2051	0.1974	0.1808	0.0152	0.0013	1.260	4.130	0.220	6.000	1.133
242	0.1318	0.1779	0.1587	0.0122	0.0070	1.270	2.500	0.200	4.000	1.850

A_{leaf}=0.1989 B_{stalk}=0.0077 C_{soil}=0.7500 D=0.4624 E=0.4000

CORRELATION COEFFICIENT=0.850

1979 SORGHUM S-31
35.6 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
156	0.0673	0.0738	0.0355	0.0004	0.0380	0.150	0.327	0.070	0.600	0.070
169		0.0947	0.0626	0.0049	0.0272	0.430	1.630	0.140	1.200	0.096
177	0.1169	0.1361	0.1208	0.0057	0.0096	0.510	2.500	0.280	3.600	0.361
191	0.1795	0.1484	0.1376	0.0101	0.0007	0.800	3.730	0.320	5.400	0.557
200	0.1774	0.1531	0.1429	0.0099	0.0003	0.950	3.580	0.320	6.500	0.668
204	0.1585	0.1546	0.1427	0.0118	0.0001	1.080	3.700	0.280	6.450	0.823
207	0.1496	0.1560	0.1433	0.0127	0.0001	1.180	3.730	0.280	6.600	0.939
208	0.1603	0.1568	0.1436	0.0131	0.0001	1.190	3.870	0.280	6.700	0.978
212	0.1742	0.1571	0.1408	0.0162	0.	1.260	4.130	0.220	6.000	1.133
242	0.1343	0.1397	0.1258	0.0133	0.0006	1.270	2.500	0.200	4.000	1.850

A_{leaf}=0.1513 B_{stalk}=0.0090 C_{soil}=0.7500 D=1.1630 E=0.4450

CORRELATION COEFFICIENT=0.907

MANHATTAN AGRICULTURAL EXPERIMENT

1979 SORGHUM S-32
8.6 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
169	0.0933	0.1094	0.0681	0.0143	0.0270	0.430	1.400	0.140	1.300	0.096
177	0.1230	0.1393	0.1070	0.0188	0.0135	0.510	2.120	0.260	2.800	0.214
191	0.1409	0.1581	0.1282	0.0286	0.0013	0.800	2.880	0.280	4.700	0.400
200	0.1862	0.1742	0.1330	0.0411	0.0002	0.950	4.000	0.300	5.600	0.785
212	0.1679	0.1899	0.1368	0.0531	0.	1.260	4.600	0.240	6.800	1.298
242	0.1581	0.1569	0.1147	0.0412	0.0011	1.270	2.050	0.160	3.300	2.155

A_{leaf}=0.1413 B_{stalk}=0.0325 C_{soil}=0.7500 D=1.1640 E=0.5055

CORRELATION COEFFICIENT=0.921

1979 SORGHUM S-32
13.0 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
169	0.0998	0.1102	0.0973	0.0038	0.0091	0.430	1.400	0.140	1.300	0.096
177	0.1288	0.1416	0.1346	0.0044	0.0026	0.510	2.120	0.260	2.800	0.214
191	0.1622	0.1534	0.1471	0.0061	0.0001	0.800	2.880	0.280	4.700	0.400
200	0.1603	0.1575	0.1489	0.0086	0.	0.950	4.000	0.300	5.600	0.785
212	0.1380	0.1609	0.1500	0.0109	0.	1.260	4.600	0.240	6.800	1.298
242	0.1698	0.1494	0.1399	0.0094	0.0001	1.270	2.050	0.160	3.300	2.155

A_{leaf}=0.1507 B_{stalk}=0.0102 C_{soil}=0.4177 D=1.3710 E=0.7990

CORRELATION COEFFICIENT=0.805

MANHATTAN AGRICULTURAL EXPERIMENT

1979 SORGHUM S-32
17.0 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
169	0.0955	0.1315	0.0806	0.0036	0.0473	0.430	1.400	0.140	1.300	0.096
177	0.1633	0.1776	0.1340	0.0050	0.0386	0.510	2.120	0.260	2.800	0.214
191	0.1950	0.1876	0.1685	0.0080	0.0110	0.800	2.880	0.280	4.700	0.400
200	0.1824	0.1935	0.1777	0.0117	0.0041	0.950	4.000	0.300	5.600	0.785
212	0.1981	0.2020	0.1858	0.0154	0.0008	1.260	4.600	0.240	6.800	1.298
242	0.1742	0.1665	0.1458	0.0111	0.0096	1.270	2.050	0.160	3.300	2.155

A_{leaf}=0.1989 B_{stalk}=0.0077 C_{soil}=0.7500 D=0.4624 E=0.4000

CORRELATION COEFFICIENT=0.944

1979 SORGHUM S-32
35.6 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
169		0.0998	0.0665	0.0041	0.0292	0.430	1.400	0.140	1.300	0.096
177	0.1094	0.1293	0.1078	0.0055	0.0160	0.510	2.120	0.260	2.800	0.214
191	0.1442	0.1430	0.1326	0.0086	0.0018	0.800	2.880	0.280	4.700	0.400
200	0.1545	0.1515	0.1388	0.0125	0.0002	0.950	4.000	0.300	5.600	0.785
212	0.1349	0.1603	0.1440	0.0163	0.	1.260	4.600	0.240	6.800	1.298
242	0.1331	0.1300	0.1165	0.0122	0.0013	1.270	2.050	0.160	3.300	2.155

A_{leaf}=0.1513 B_{stalk}=0.0090 C_{soil}=0.7500 D=1.1630 E=0.4450

CORRELATION COEFFICIENT=0.600

MANHATTAN AGRICULTURAL EXPERIMENT

1979 SORGHUM S-33
8.6 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
169	0.1012	0.0778	0.0316	0.0173	0.0289	0.430	1.400	0.100	0.500	0.085
177	0.1119	0.1206	0.0681	0.0409	0.0116	0.510	3.369	0.220	1.300	0.251
191	0.1449	0.1764	0.1330	0.0432	0.0001	0.800	5.000	0.300	5.600	0.636
200	0.1742	0.1735	0.1330	0.0403	0.0002	0.950	3.929	0.280	5.600	0.817
212	0.1603	0.1802	0.1330	0.0472	0.0001	1.260	3.465	0.220	5.600	1.058
247	0.1549	0.1489	0.1172	0.0304	0.0013	1.270	1.570	0.100	3.500	1.762

A_{leaf}=0.1413 B_{stalk}=0.0325 C_{soil}=0.7500 D=1.1640 E=0.5055

CORRELATION COEFFICIENT=0.896

1979 SORGHUM S-33
13.0 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
169	0.0908	0.0670	0.0496	0.0051	0.0123	0.430	1.400	0.100	0.500	0.085
177	0.1140	0.1114	0.0973	0.0109	0.0031	0.510	3.369	0.220	1.300	0.251
191	0.1346	0.1580	0.1489	0.0090	0.	0.800	5.000	0.300	5.600	0.636
200	0.1469	0.1574	0.1489	0.0084	0.	0.950	3.929	0.280	5.600	0.817
212	0.1361	0.1588	0.1489	0.0099	0.	1.260	3.465	0.220	5.600	1.058
247	0.1578	0.1485	0.1415	0.0069	0.0002	1.270	1.570	0.100	3.500	1.762

A_{leaf}=0.1507 B_{stalk}=0.0102 C_{soil}=0.4177 D=1.3710 E=0.7990

CORRELATION COEFFICIENT=0.900

MANHATTAN AGRICULTURAL EXPERIMENT

1979 SORGHUM S-33
17.0 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
169	0.1021	0.0867	0.0361	0.0042	0.0465	0.430	1.400	0.100	0.500	0.085
177	0.1570	0.1353	0.0806	0.0103	0.0443	0.510	3.369	0.220	1.300	0.251
191	0.1841	0.1938	0.1777	0.0123	0.0038	0.800	5.000	0.300	5.600	0.636
200	0.2000	0.1932	0.1777	0.0115	0.0040	0.950	3.929	0.280	5.600	0.817
212	0.1862	0.1935	0.1777	0.0134	0.0023	1.260	3.465	0.220	5.600	1.058
247	0.1380	0.1655	0.1498	0.0083	0.0074	1.270	1.570	0.100	3.500	1.762

A_{leaf}=0.1989 B_{stalk}=0.0077 C_{soil}=0.7500 D=0.4624 E=0.4000

CORRELATION COEFFICIENT=0.910

1979 SORGHUM S-33
35.6 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
169		0.0648	0.0302	0.0048	0.0298	0.430	1.400	0.100	0.500	0.085
177	0.0991	0.0907	0.0665	0.0117	0.0125	0.510	3.369	0.220	1.300	0.251
191	0.1412	0.1521	0.1388	0.0132	0.0002	0.800	5.000	0.300	5.600	0.636
200	0.1384	0.1513	0.1388	0.0123	0.0002	0.950	3.929	0.280	5.600	0.817
212	0.1151	0.1532	0.1388	0.0144	0.0001	1.260	3.465	0.220	5.600	1.058
247	0.1091	0.1300	0.1194	0.0090	0.0016	1.270	1.570	0.100	3.500	1.762

A_{leaf}=0.1513 B_{stalk}=0.0090 C_{soil}=0.7500 D=1.1630 E=0.4450

CORRELATION COEFFICIENT=0.783

MANHATTAN AGRICULTURAL EXPERIMENT

1979 SORGHUM S-34
8.6 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
171	0.1042	0.1044	0.0717	0.0163	0.0164	0.500	1.400	0.100	1.400	0.106
178	0.1479	0.1458	0.1087	0.0307	0.0064	0.600	3.000	0.300	2.900	0.386
192	0.1660	0.1647	0.1294	0.0346	0.0007	0.820	3.500	0.320	4.889	0.758
201	0.1910	0.1750	0.1336	0.0412	0.0001	1.000	3.900	0.300	5.758	1.135
213	0.1742	0.1835	0.1368	0.0467	0.	1.270	4.020	0.200	6.800	1.512
247	0.1510	0.1463	0.1147	0.0301	0.0015	1.270	1.500	0.100	3.300	1.832

A_{leaf}=0.1413 B_{stalk}=0.0325 C_{soil}=0.7500 D=1.1640 E=0.5055

CORRELATION COEFFICIENT=0.961

1979 SORGHUM S-34
13.0 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
171	0.0933	0.1110	0.1014	0.0043	0.0052	0.500	1.400	0.100	1.400	0.106
178	0.1380	0.1440	0.1358	0.0072	0.0010	0.600	3.000	0.300	2.900	0.386
192	0.1622	0.1550	0.1476	0.0074	0.0001	0.820	3.500	0.320	4.889	0.758
201	0.1449	0.1577	0.1491	0.0086	0.	1.000	3.900	0.300	5.758	1.135
213	0.1432	0.1596	0.1500	0.0096	0.	1.270	4.020	0.200	6.800	1.512
247	0.1503	0.1470	0.1399	0.0069	0.0002	1.270	1.500	0.100	3.300	1.832

A_{leaf}=0.1507 B_{stalk}=0.0102 C_{soil}=0.4177 D=1.3710 E=0.7990

CORRELATION COEFFICIENT=0.910

MANHATTAN ACRICULTURAL EXPERIMENT

1979 SORGHUM S-34
17.0 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
171	0.1256	0.1204	0.0853	0.0041	0.0310	0.500	1.400	0.100	1.400	0.106
178	0.1820	0.1754	0.1365	0.0082	0.0307	0.600	3.000	0.300	2.900	0.386
192	0.2148	0.1895	0.1708	0.0097	0.0090	0.820	3.500	0.320	4.889	0.758
201	0.1981	0.1945	0.1790	0.0118	0.0037	1.000	3.900	0.300	5.758	1.135
213	0.1968	0.2002	0.1858	0.0135	0.0009	1.270	4.020	0.200	6.800	1.512
247	0.1380	0.1622	0.1458	0.0082	0.0083	1.270	1.500	0.100	3.300	1.832

A_{leaf}=0.1989 B_{stalk}=0.0077 C_{soil}=0.7500 D=0.4624 E=0.4000

CORRELATION COEFFICIENT=0.897

1979 SORGHUM S-34
35.6 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
171	0.1071	0.0926	0.0702	0.0047	0.0178	0.500	1.400	0.100	1.400	0.106
178	0.0887	0.1264	0.1097	0.0091	0.0076	0.600	3.000	0.300	2.900	0.386
192	0.1242	0.1456	0.1341	0.0105	0.0010	0.820	3.500	0.320	4.889	0.758
201	0.1614	0.1524	0.1396	0.0126	0.0002	1.000	3.900	0.300	5.758	1.135
213	0.1660	0.1583	0.1440	0.0144	0.	1.270	4.020	0.200	6.800	1.512
247	0.1455	0.1273	0.1165	0.0089	0.0019	1.270	1.500	0.100	3.300	1.832

A_{leaf}=0.1513 B_{stalk}=0.0090 C_{soil}=0.7500 D=1.1630 E=0.4450

CORRELATION COEFFICIENT=0.688

MANHATTAN AGRICULTURAL EXPERIMENT

1979 SORGHUM S-35
8.6 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
171	0.0940	0.0992	0.0561	0.0128	0.0304	0.500	1.000	0.120	1.000	0.079
178	0.1321	0.1401	0.1133	0.0177	0.0091	0.600	1.830	0.220	3.200	0.325
192	0.1698	0.1585	0.1300	0.0272	0.0012	0.820	2.800	0.300	5.000	0.476
201	0.1778	0.1705	0.1360	0.0343	0.0001	1.000	3.600	0.320	6.500	1.074
213	0.1950	0.1853	0.1368	0.0485	0.	1.270	4.170	0.200	6.800	1.871
254	0.1585	0.1418	0.1052	0.0302	0.0064	1.270	1.340	0.240	2.700	2.400

A_{leaf}=0.1413 B_{stalk}=0.0325 C_{soil}=0.7500 D=1.1640 E=0.5055

CORRELATION COEFFICIENT=0.975

1979 SORGHUM S-35
13.0 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
171	0.0869	0.0978	0.0829	0.0035	0.0114	0.500	1.000	0.120	1.000	0.079
178	0.1282	0.1446	0.1390	0.0041	0.0016	0.600	1.830	0.220	3.200	0.325
192	0.1510	0.1538	0.1479	0.0058	0.0001	0.820	2.800	0.300	5.000	0.476
201	0.1702	0.1569	0.1498	0.0071	0.	1.000	3.600	0.320	6.500	1.074
213	0.1778	0.1599	0.1500	0.0099	0.	1.270	4.170	0.200	6.800	1.871
254	0.1905	0.1415	0.1332	0.0071	0.0011	1.270	1.340	0.240	2.700	2.400

A_{leaf}=0.1507 B_{stalk}=0.0102 C_{soil}=0.4177 D=1.3710 E=0.7990

CORRELATION COEFFICIENT=0.803

MANHATTAN AGRICULTURAL EXPERIMENT

1979 SORGHUM S-35
17.0 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
171	0.1230	0.1166	0.0656	0.0032	0.0479	0.500	1.000	0.120	1.000	0.079
178	0.1675	0.1760	0.1436	0.0048	0.0276	0.600	1.830	0.220	3.200	0.325
192	0.1807	0.1902	0.1720	0.0077	0.0105	0.820	2.800	0.300	5.000	0.476
201	0.2051	0.1974	0.1841	0.0099	0.0034	1.000	3.600	0.320	6.500	1.074
213	0.2051	0.2007	0.1858	0.0140	0.0009	1.270	4.170	0.200	6.800	1.871
254	0.1698	0.1672	0.1313	0.0080	0.0278	1.270	1.340	0.240	2.700	2.400

A_{leaf}=0.1989 B_{stalk}=0.0077 C_{soil}=0.7500 D=0.4624 E=0.4000

CORRELATION COEFFICIENT=0.970

1979 SORGHUM S-35
35.6 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
171	0.0910	0.0902	0.0543	0.0036	0.0322	0.500	1.000	0.120	1.000	0.079
178	0.1114	0.1312	0.1149	0.0052	0.0111	0.600	1.830	0.220	3.200	0.325
192	0.1578	0.1449	0.1349	0.0082	0.0017	0.820	2.800	0.300	5.000	0.476
201	0.1778	0.1536	0.1429	0.0105	0.0002	1.000	3.600	0.320	6.500	1.074
213	0.1622	0.1589	0.1440	0.0149	0.	1.270	4.170	0.200	6.800	1.871
254	0.1622	0.1221	0.1058	0.0089	0.0075	1.270	1.340	0.240	2.700	2.400

A_{leaf}=0.1513 B_{stalk}=0.0090 C_{soil}=0.7500 D=1.1630 E=0.4450

CORRELATION COEFFICIENT=0.801

MANHATTAN AGRICULTURAL EXPERIMENT

1979 SORGHUM S-36
8.6 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
171	0.0944	0.0838	0.0259	0.0118	0.0462	0.500	0.800	0.120	0.400	0.066
178	0.1409	0.1262	0.0681	0.0453	0.0128	0.600	3.170	0.300	1.300	0.249
192	0.1510	0.1761	0.1288	0.0471	0.0002	0.820	4.700	0.300	4.800	0.587
201	0.2000	0.1835	0.1345	0.0490	0.	1.000	4.800	0.340	6.000	1.352
213	0.1778	0.1896	0.1345	0.0551	0.	1.270	4.250	0.200	6.000	1.562
254	0.1563	0.1605	0.1196	0.0398	0.0012	1.270	2.130	0.240	3.700	2.489

A_{leaf}=0.1413 B_{stalk}=0.0325 C_{soil}=0.7500 D=1.1640 E=0.5055

CORRELATION COEFFICIENT=0.914

1979 SORGHUM S-36
13.0 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
171	0.0760	0.0658	0.0412	0.0035	0.0210	0.500	0.800	0.120	0.400	0.066
178	0.0851	0.1127	0.0973	0.0121	0.0033	0.600	3.170	0.300	1.300	0.249
192	0.1346	0.1575	0.1474	0.0101	0.	0.820	4.700	0.300	4.800	0.587
201	0.1585	0.1596	0.1494	0.0102	0.	1.000	4.800	0.340	6.000	1.352
213	0.1622	0.1608	0.1494	0.0114	0.	1.270	4.250	0.200	6.000	1.562
254	0.2004	0.1518	0.1428	0.0089	0.0001	1.270	2.130	0.240	3.700	2.489

A_{leaf}=0.1507 B_{stalk}=0.0102 C_{soil}=0.4177 D=1.3710 E=0.7990

CORRELATION COEFFICIENT=0.822

MANHATTAN AGRICULTURAL EXPERIMENT

1979 SORGHUM S-36
17.0 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
171	0.1200	0.0960	0.0294	0.0029	0.0637	0.500	0.800	0.120	0.400	0.066
178	0.1445	0.1476	0.0806	0.0114	0.0555	0.600	3.170	0.300	1.300	0.249
192	0.1702	0.1885	0.1697	0.0132	0.0056	0.820	4.700	0.300	4.800	0.587
201	0.2023	0.1974	0.1808	0.0140	0.0025	1.000	4.800	0.340	6.000	1.352
213	0.1706	0.1977	0.1808	0.0158	0.0011	1.270	4.250	0.200	6.000	1.562
254	0.1486	0.1762	0.1536	0.0109	0.0117	1.270	2.130	0.240	3.700	2.489

A_{leaf}=0.1989 B_{stalk}=0.0077 C_{soil}=0.7500 D=0.4624 E=0.4000

CORRELATION COEFFICIENT=0.873

1979 SORGHUM S-36
35.6 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
171	0.1033	0.0753	0.0247	0.0033	0.0473	0.500	0.800	0.120	0.400	0.066
178	0.0841	0.0932	0.0665	0.0129	0.0138	0.600	3.170	0.300	1.300	0.249
192	0.1178	0.1480	0.1334	0.0142	0.0003	0.820	4.700	0.300	4.800	0.587
201	0.1679	0.1559	0.1408	0.0150	0.0001	1.000	4.800	0.340	6.000	1.352
213	0.1618	0.1577	0.1408	0.0168	0.	1.270	4.250	0.200	6.000	1.562
254	0.1660	0.1355	0.1221	0.0119	0.0015	1.270	2.130	0.240	3.700	2.489

A_{leaf}=0.1513 B_{stalk}=0.0090 C_{soil}=0.7500 D=1.1630 E=0.4450

CORRELATION COEFFICIENT=0.792

APPENDIX C - 1979 Corn Data

Observed values of the backscattering coefficients, predicted values, ground-truth values, and correlation between predicted and observed backscattering coefficients, and model values for six corn fields.

MODEL EQUATION

$$\sigma^{o}_{pred} = \sigma^{o}_{leaf} + \sigma^{o}_{stalk} + \sigma^{o}_{soil}$$

$$= A_{leaf}\,(1 - e^{-E \cdot LAI})$$

$$+ \frac{B_{stalk} \cdot W \cdot H}{E \cdot LAI}\,(1 - e^{-E \cdot LAI})$$

$$\cdot\, e^{-D \cdot W \cdot H}\, e^{E \cdot LAI}$$

$$+ C_{soil} \cdot m_s$$

Symbol	SI Units	Description
σ^{o}_{pred}	$m^2\ m^{-2}$	Predicted backscattering cross section coefficient
σ^{o}_{leaf}	$m^2\ m^{-2}$	Backscattering cross section coefficient for leaf contribution
σ^{o}_{stalk}	$m^2\ m^{-2}$	Backscattering cross section coefficient for stalk contribution
σ^{o}_{soil}	$m^2\ m^{-2}$	Backscattering cross section coefficient for soil contribution
LAI	$m^2\ m^{-2}$	Leaf Area Index
H	m	crop canopy height
W	$kg\ m^{-3}$	Volumetric normalized plant water content
m_s	$kg\ m^{-3}$	Volumetric soil moisture content
A_{leaf}	----	Empirical coefficient for leaf contribution to predicted radar backscatter
B_{stalk}	----	Empirical coefficient for stalk contribution to predicted radar backscatter
C_{soil}	----	Empirical coefficient for soil contribution to predicted radar backscatter
D	nepers $m\ kg^{-1}$	Empirical attenuation coefficient for attenuation due to plant water
E	nepers	Empirical attenuation constant for attenuation due to leaves
ρ	----	Correlation coefficient between predicted and observed backscatter coefficients

MANHATTAN AGRICULTURAL EXPERIMENT

1979 CORN C-11
8.6 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
156	0.0586	0.0590	0.0273	0.0001	0.0316	0.250	0.300	0.140	0.400	0.037
169	0.0681	0.0861	0.0775	0.0007	0.0079	0.520	0.960	0.200	1.400	0.130
177	0.1049	0.1010	0.0984	0.0017	0.0008	0.800	1.630	0.320	2.000	0.225
191	0.1585	0.1423	0.1389	0.0035	0.	1.810	2.070	0.360	4.010	0.624
200	0.1694	0.1544	0.1496	0.0048	0.	2.500	2.440	0.320	5.100	0.805
204	0.1567	0.1549	0.1496	0.0053	0.	2.650	2.540	0.300	5.100	0.885
207	0.1901	0.1553	0.1496	0.0057	0.	2.750	2.640	0.300	5.100	0.946
208	0.1738	0.1554	0.1496	0.0059	0.	2.710	2.750	0.300	5.100	0.966
212	0.1409	0.1540	0.1480	0.0060	0.	2.650	2.800	0.280	4.900	1.046
226		0.1570	0.1522	0.0048	0.	2.500	2.560	0.220	5.470	1.328
228		0.1562	0.1514	0.0048	0.	2.500	2.520	0.200	5.352	1.841
242	0.0977	0.1275	0.1230	0.0045	0.	2.500	1.640	0.180	3.000	2.598

A_{leaf}=0.1667 B_{stalk}=0.0020 C_{soil}=0.3388 D=3.0470 E=0.4464

CORRELATION COEFFICIENT=0.924

1979 CORN C-11
13.0 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
156	0.0575	0.0608	0.0265	0.0002	0.0340	0.250	0.300	0.140	0.400	0.037
169	0.0767	0.0791	0.0724	0.0010	0.0057	0.520	0.960	0.200	1.400	0.130
177	0.0851	0.0927	0.0901	0.0023	0.0003	0.800	1.630	0.320	2.000	0.225
191	0.1396	0.1250	0.1206	0.0044	0.	1.810	2.070	0.360	4.010	0.624
200	0.1337	0.1334	0.1275	0.0059	0.	2.500	2.440	0.320	5.100	0.805
204	0.1472	0.1340	0.1275	0.0065	0.	2.650	2.540	0.300	5.100	0.885
207	0.1396	0.1345	0.1275	0.0071	0.	2.750	2.640	0.300	5.100	0.946
208	0.1449	0.1347	0.1275	0.0072	0.	2.710	2.750	0.300	5.100	0.966
212	0.1349	0.1339	0.1265	0.0074	0.	2.650	2.800	0.280	4.900	1.046
226		0.1349	0.1290	0.0059	0.	2.500	2.560	0.220	5.470	1.328
228		0.1344	0.1286	0.0059	0.	2.500	2.520	0.200	5.352	1.841
242	0.1122	0.1151	0.1093	0.0058	0.	2.500	1.640	0.180	3.000	2.598

A_{leaf}=0.1360 B_{stalk}=0.0029 C_{soil}=0.4008 D=3.7740 E=0.5426

CORRELATION COEFFICIENT=0.983

MANHATTAN AGRICULTURAL EXPERIMENT

1979 CORN C-11
17.0 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
156	0.0871	0.0777	0.0355	0.0001	0.0422	0.250	0.300	0.140	0.400	0.037
169	0.0933	0.1035	0.0962	0.0003	0.0069	0.520	0.960	0.200	1.400	0.130
177	0.1496	0.1205	0.1193	0.0008	0.0004	0.800	1.630	0.320	2.000	0.225
191	0.1862	0.1600	0.1585	0.0015	0.	1.810	2.070	0.360	4.010	0.624
200	0.2075	0.1692	0.1672	0.0020	0.	2.500	2.440	0.320	5.100	0.805
204	0.2239	0.1694	0.1672	0.0022	0.	2.650	2.540	0.300	5.100	0.885
207	0.1919	0.1696	0.1672	0.0024	0.	2.750	2.640	0.300	5.100	0.946
208	0.1866	0.1696	0.1672	0.0025	0.	2.710	2.750	0.300	5.100	0.966
212	0.1738	0.1685	0.1660	0.0025	0.	2.650	2.800	0.280	4.900	1.046
226		0.1711	0.1691	0.0020	0.	2.500	2.560	0.220	5.470	1.328
228		0.1705	0.1685	0.0020	0.	2.500	2.520	0.200	5.352	1.841
242	0.1358	0.1462	0.1442	0.0020	0.	2.500	1.640	0.180	3.000	2.598

A_{leaf}=0.1775 B_{stalk}=0.0010 C_{soil}=0.5000 D=3.7850 E=0.5576

CORRELATION COEFFICIENT=0.918

1979 CORN C-11
35.6 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
156	0.0589	0.0525	0.0285	0.0001	0.0239	0.250	0.300	0.140	0.400	0.037
169		0.0857	0.0826	0.0004	0.0027	0.520	0.960	0.200	1.400	0.130
177	0.1202	0.1070	0.1060	0.0009	0.0001	0.800	1.630	0.320	2.000	0.225
191	0.2089	0.1557	0.1538	0.0019	0.	1.810	2.070	0.360	4.010	0.624
200	0.1841	0.1701	0.1675	0.0026	0.	2.500	2.440	0.320	5.100	0.805
204	0.2089	0.1704	0.1675	0.0029	0.	2.650	2.540	0.300	5.100	0.885
207	0.1905	0.1706	0.1675	0.0031	0.	2.750	2.640	0.300	5.100	0.946
208	0.1936	0.1707	0.1675	0.0032	0.	2.710	2.750	0.300	5.100	0.966
212	0.1581	0.1687	0.1654	0.0033	0.	2.650	2.800	0.280	4.900	1.046
226		0.1735	0.1709	0.0026	0.	2.500	2.560	0.220	5.470	1.328
228		0.1725	0.1699	0.0026	0.	2.500	2.520	0.200	5.352	1.841
242	0.1069	0.1369	0.1345	0.0024	0.	2.500	1.640	0.180	3.000	2.598

A_{leaf}=0.1925 B_{stalk}=0.0010 C_{soil}=0.2917 D=5.0000 E=0.4000

CORRELATION COEFFICIENT=0.890

MANHATTAN AGRICULTURAL EXPERIMENT

1979 CORN C-12
8.6 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
156		0.0624	0.0209	0.	0.0415	0.250	0.	0.140	0.300	0.024
169	0.0555	0.0533	0.0333	0.0005	0.0195	0.520	0.580	0.180	0.500	0.040
177	0.0661	0.0768	0.0734	0.0018	0.0016	0.800	1.500	0.320	1.300	0.122
191	0.1318	0.1299	0.1249	0.0050	0.	1.810	2.540	0.320	3.100	0.415
200	0.1291	0.1378	0.1317	0.0061	0.	2.500	2.400	0.300	3.500	0.814
212	0.1047	0.1425	0.1347	0.0077	0.	2.560	3.090	0.280	3.700	1.346
228		0.1466	0.1411	0.0055	0.	2.500	2.440	0.200	4.200	2.000
242	0.0977	0.1175	0.1121	0.0054	0.	2.500	1.800	0.180	2.500	2.583

A_{leaf}=0.1667 B_{stalk}=0.0020 C_{soil}=0.3388 D=3.0470 E=0.4464

CORRELATION COEFFICIENT=0.912

1979 CORN C-12
13.0 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
156		0.0681	0.0204	0.	0.0477	0.250	0.	0.140	0.300	0.024
169	0.0630	0.0507	0.0323	0.0008	0.0176	0.520	0.580	0.180	0.500	0.040
177	0.0879	0.0720	0.0688	0.0025	0.0007	0.800	1.500	0.320	1.300	0.122
191	0.1219	0.1171	0.1107	0.0064	0.	1.810	2.540	0.320	3.100	0.415
200	0.1449	0.1234	0.1157	0.0077	0.	2.500	2.400	0.300	3.500	0.814
212	0.1259	0.1275	0.1178	0.0098	0.	2.560	3.090	0.280	3.700	1.346
228		0.1290	0.1221	0.0069	0.	2.500	2.440	0.200	4.200	2.000
242	0.1122	0.1081	0.1010	0.0071	0.	2.500	1.800	0.180	2.500	2.583

A_{leaf}=0.1360 B_{stalk}=0.0029 C_{soil}=0.4008 D=3.7740 E=0.5426

CORRELATION COEFFICIENT=0.962

MANHATTAN AGRICULTURAL EXPERIMENT

1979 CORN C-12
17.0 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
156		0.0866	0.0273	0.	0.0592	0.250	0.	0.140	0.300	0.024
169	0.0851	0.0652	0.0432	0.0003	0.0217	0.520	0.580	0.180	0.500	0.040
177	0.1067	0.0932	0.0915	0.0009	0.0008	0.800	1.500	0.320	1.300	0.122
191	0.1791	0.1482	0.1460	0.0022	0.	1.810	2.540	0.320	3.100	0.415
200	0.1535	0.1549	0.1523	0.0026	0.	2.500	2.400	0.300	3.500	0.814
212	0.1581	0.1583	0.1550	0.0033	0.	2.560	3.090	0.280	3.700	1.346
228		0.1628	0.1604	0.0024	0.	2.500	2.440	0.200	4.200	2.000
242	0.1297	0.1359	0.1335	0.0024	0.	2.500	1.800	0.180	2.500	2.583

A_{leaf}=0.1775 B_{stalk}=0.0010 C_{soil}=0.5000 D=3.7850 E=0.5576

CORRELATION COEFFICIENT=0.925

1979 CORN C-12
35.6 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
156		0.0580	0.0218	0.	0.0362	0.250	0.	0.140	0.300	0.024
169		0.0447	0.0349	0.0003	0.0095	0.520	0.580	0.180	0.500	0.040
177	0.0851	0.0791	0.0781	0.0009	0.0001	0.800	1.500	0.320	1.300	0.122
191	0.1545	0.1395	0.1368	0.0026	0.	1.810	2.540	0.320	3.100	0.415
200	0.1479	0.1483	0.1451	0.0032	0.	2.500	2.400	0.300	3.500	0.814
212	0.1259	0.1528	0.1487	0.0041	0.	2.560	3.090	0.280	3.700	1.346
228		0.1596	0.1567	0.0030	0.	2.500	2.440	0.200	4.200	2.000
242	0.1230	0.1246	0.1217	0.0028	0.	2.500	1.800	0.180	2.500	2.583

A_{leaf}=0.1925 B_{stalk}=0.0010 C_{soil}=0.2917 D=5.0000 E=0.4000

CORRELATION COEFFICIENT=0.853

MANHATTAN AGRICULTURAL EXPERIMENT

1979 CORN C-13
8.6 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
156		0.0526	0.0073	0.	0.0454	0.250	0.	0.140	0.100	0.009
169	0.0598	0.0472	0.0209	0.0004	0.0260	0.520	0.380	0.160	0.300	0.027
177	0.0646	0.0765	0.0734	0.0020	0.0011	0.800	1.630	0.320	1.300	0.128
191	0.1259	0.1029	0.0984	0.0045	0.	1.810	1.880	0.300	2.000	0.266
200	0.1288	0.1078	0.1014	0.0064	0.	2.500	1.960	0.300	2.100	0.539
212	0.1225	0.1211	0.1145	0.0067	0.	2.560	2.200	0.240	2.600	0.902
228		0.1227	0.1167	0.0059	0.	2.500	2.040	0.200	2.700	1.234
247	0.0914	0.0859	0.0814	0.0045	0.	2.500	1.240	0.120	1.500	1.580

A_{leaf}=0.1667 B_{stalk}=0.0020 C_{soil}=0.3388 D=3.0470 E=0.4464

CORRELATION COEFFICIENT=0.912

1979 CORN C-13
13.0 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
156		0.0603	0.0072	0.	0.0531	0.250	0.	0.140	0.100	0.009
169	0.0655	0.0468	0.0204	0.0005	0.0258	0.520	0.380	0.160	0.300	0.027
177	0.0638	0.0720	0.0688	0.0027	0.0005	0.800	1.630	0.320	1.300	0.128
191	0.1253	0.0960	0.0901	0.0060	0.	1.810	1.880	0.300	2.000	0.266
200	0.1084	0.1009	0.0925	0.0084	0.	2.500	1.960	0.300	2.100	0.539
212	0.1069	0.1115	0.1028	0.0087	0.	2.560	2.200	0.240	2.600	0.902
228		0.1123	0.1046	0.0077	0.	2.500	2.040	0.200	2.700	1.234
247	0.0867	0.0818	0.0757	0.0061	0.	2.500	1.240	0.120	1.500	1.580

A_{leaf}=0.1360 B_{stalk}=0.0029 C_{soil}=0.4008 D=3.7740 E=0.5426

CORRELATION COEFFICIENT=0.831

MANHATTAN AGRICULTURAL EXPERIMENT

1979 CORN C-13
17.0 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
156		0.0758	0.0096	0.	0.0662	0.250	0.	0.140	0.100	0.009
169	0.0813	0.0596	0.0273	0.0002	0.0320	0.520	0.380	0.160	0.300	0.027
177	0.0977	0.0930	0.0915	0.0009	0.0006	0.800	1.630	0.320	1.300	0.128
191	0.1578	0.1214	0.1193	0.0021	0.	1.810	1.880	0.300	2.000	0.266
200	0.1517	0.1254	0.1225	0.0029	0.	2.500	1.960	0.300	2.100	0.539
212	0.1517	0.1388	0.1359	0.0030	0.	2.560	2.200	0.240	2.600	0.902
228		0.1408	0.1381	0.0026	0.	2.500	2.040	0.200	2.700	1.234
247	0.1291	0.1027	0.1006	0.0021	0.	2.500	1.240	0.120	1.500	1.580

A_{leaf}=0.1775 B_{stalk}=0.0010 C_{soil}=0.5000 D=3.7850 E=0.5576

CORRELATION COEFFICIENT=0.938

1979 CORN C-13
35.6 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
156		0.0468	0.0075	0.	0.0392	0.250	0.	0.140	0.100	0.009
169		0.0374	0.0218	0.0002	0.0154	0.520	0.380	0.160	0.300	0.027
177	0.0906	0.0792	0.0781	0.0010	0.0001	0.800	1.630	0.320	1.300	0.128
191	0.1151	0.1084	0.1060	0.0023	0.	1.810	1.880	0.300	2.000	0.266
200	0.1151	0.1127	0.1094	0.0033	0.	2.500	1.960	0.300	2.100	0.539
212	0.1125	0.1280	0.1245	0.0035	0.	2.560	2.200	0.240	2.600	0.902
228		0.1303	0.1272	0.0031	0.	2.500	2.040	0.200	2.700	1.234
247	0.1071	0.0892	0.0869	0.0023	0.	2.500	1.240	0.120	1.500	1.580

A_{leaf}=0.1925 B_{stalk}=0.0010 C_{soil}=0.2917 D=5.0000 E=0.4000

CORRELATION COEFFICIENT=0.807

MANHATTAN AGRICULTURAL EXPERIMENT

1979 CORN C-14
8.6 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
156		0.0713	0.0333	0.	0.0379	0.250	0.	0.140	0.500	0.045
171	0.0804	0.0813	0.0775	0.0009	0.0029	0.610	0.980	0.100	1.400	0.094
178	0.1127	0.1037	0.0999	0.0038	0.	0.810	3.580	0.240	2.050	0.118
192	0.1245	0.1488	0.1422	0.0066	0.	1.960	3.780	0.280	4.300	0.930
201	0.1607	0.1578	0.1503	0.0075	0.	2.480	3.870	0.300	5.200	1.429
213	0.1445	0.1561	0.1488	0.0073	0.	2.500	3.650	0.200	5.000	1.574
228		0.1602	0.1557	0.0045	0.	2.500	2.600	0.200	6.100	1.699
247	0.1114	0.1268	0.1210	0.0058	0.	2.500	2.080	0.120	2.900	1.825

A_{leaf}=0.1667 B_{stalk}=0.0020 C_{soil}=0.3388 D=3.0470 E=0.4464

CORRELATION COEFFICIENT=0.916

1979 CORN C-14
13.0 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
156		0.0751	0.0323	0.	0.0428	0.250	0.	0.140	0.500	0.045
171	0.0708	0.0756	0.0724	0.0012	0.0020	0.610	0.980	0.100	1.400	0.094
178	0.0805	0.0963	0.0913	0.0050	0.	0.810	3.580	0.240	.0	0.118
192	0.1315	0.1311	0.1228	0.0082	0.	1.960	3.780	0.280	4.300	0.930
201	0.1288	0.1371	0.1279	0.0092	0.	2.480	3.870	0.300	5.200	1.429
213	0.1230	0.1360	0.1270	0.0090	0.	2.500	3.650	0.200	5.000	1.574
228		0.1365	0.1310	0.0054	0.	2.500	2.600	0.200	6.100	1.699
247	0.0771	0.1153	0.1078	0.0075	0.	2.500	2.080	0.120	2.900	1.825

A_{leaf}=0.1360 B_{stalk}=0.0029 C_{soil}=0.4008 D=3.7740 E=0.5426

CORRELATION COEFFICIENT=0.881

MANHATTAN AGRICULTURAL EXPERIMENT

1979 CORN C-14
17.0 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
156		0.0962	0.0432	0.	0.0530	0.250	0.	0.140	0.500	0.045
171	0.0776	0.0990	0.0962	0.0004	0.0024	0.610	0.980	0.100	1.400	0.094
178	0.1148	0.1226	0.1209	0.0017	0.	0.810	3.580	0.240	2.050	0.118
192	0.1352	0.1642	0.1614	0.0028	0.	1.960	3.780	0.280	4.300	0.930
201	0.1074	0.1709	0.1677	0.0031	0.	2.480	3.870	0.300	5.200	1.429
213	0.1439	0.1697	0.1666	0.0031	0.	2.500	3.650	0.200	5.000	1.574
228		0.1734	0.1716	0.0018	0.	2.500	2.600	0.200	6.100	1.699
247	0.1268	0.1449	0.1423	0.0026	0.	2.500	2.080	0.120	2.900	1.825

A_{leaf}=0.1775 B_{stalk}=0.0010 C_{soil}=0.5000 D=3.7850 E=0.5576

CORRELATION COEFFICIENT=0.760

1979 CORN C-14
35.6 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
156		0.0683	0.0349	0.	0.0334	0.250	0.	0.140	0.500	0.045
171	0.1000	0.0839	0.0826	0.0005	0.0008	0.610	0.980	0.100	1.400	0.094
178	0.1346	0.1097	0.1077	0.0020	0.	0.810	3.580	0.240	2.050	0.118
192	0.1507	0.1616	0.1581	0.0035	0.	1.960	3.780	0.280	4.300	0.930
201	0.1778	0.1725	0.1685	0.0040	0.	2.480	3.870	0.300	5.200	1.429
213	0.1368	0.1704	0.1665	0.0039	0.	2.500	3.650	0.200	5.000	1.574
228		0.1782	0.1758	0.0024	0.	2.500	2.600	0.200	6.100	1.699
247	0.0955	0.1353	0.1322	0.0031	0.	2.500	2.080	0.120	2.900	1.825

A_{leaf}=0.1925 B_{stalk}=0.0010 C_{soil}=0.2917 D=5.0000 E=0.4000

CORRELATION COEFFICIENT=0.700

MANHATTAN AGRICULTURAL EXPERIMENT

1979 CORN C-15
8.6 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
156		0.0624	0.0209	0.	0.0415	0.250	0.	0.140	0.300	0.021
171	0.0908	0.0751	0.0600	0.0007	0.0144	0.610	0.690	0.240	1.000	0.052
178	0.0989	0.0912	0.0886	0.0022	0.0003	0.810	1.980	0.240	1.700	0.215
192	0.1186	0.1237	0.1189	0.0048	0.	1.960	2.140	0.060	2.800	0.593
201	0.1472	0.1302	0.1249	0.0053	0.	2.480	1.980	0.320	3.100	1.322
213	0.1318	0.1357	0.1301	0.0056	0.	2.500	2.160	0.200	3.400	2.370
228		0.1298	0.1249	0.0049	0.	2.500	1.800	0.200	3.100	2.399
254	0.1045	0.0926	0.0886	0.0039	0.	2.500	1.120	0.240	1.700	2.449

A_{leaf}=0.1667 B_{stalk}=0.0020 C_{soil}=0.3388 D=3.0470 E=0.4464

CORRELATION COEFFICIENT=0.925

1979 CORN C-15
13.0 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
156		0.0681	0.0204	0.	0.0477	0.250	0.	0.140	0.300	0.021
171	0.0569	0.0693	0.0570	0.0009	0.0114	0.610	0.690	0.240	1.000	0.052
178	0.0671	0.0850	0.0819	0.0030	0.0001	0.810	1.980	0.240	1.700	0.215
192	0.1094	0.1124	0.1062	0.0062	0.	1.960	2.140	0.060	2.800	0.593
201	0.1191	0.1175	0.1107	0.0068	0.	2.480	1.980	0.320	3.100	1.322
213	0.1023	0.1216	0.1145	0.0071	0.	2.500	2.160	0.200	3.400	2.370
228		0.1170	0.1107	0.0062	0.	2.500	1.800	0.200	3.100	2.399
254	0.1091	0.0872	0.0819	0.0052	0.	2.500	1.120	0.240	1.700	2.449

A_{leaf}=0.1360 B_{stalk}=0.0029 C_{soil}=0.4008 D=3.7740 E=0.5426

CORRELATION COEFFICIENT=0.796

MANHATTAN AGRICULTURAL EXPERIMENT

1979 CORN C-15
17.0 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
156		0.0866	0.0273	0.	0.0592	0.250	0.	0.140	0.300	0.021
171	0.0794	0.0902	0.0759	0.0003	0.0140	0.610	0.690	0.240	1.000	0.052
178	0.0955	0.1099	0.1087	0.0010	0.0001	0.810	1.980	0.240	1.700	0.215
192	0.1191	0.1424	0.1403	0.0021	0.	1.960	2.140	0.060	2.800	0.593
201	0.1178	0.1483	0.1460	0.0023	0.	2.480	1.980	0.320	3.100	1.322
213	0.1122	0.1533	0.1509	0.0024	0.	2.500	2.160	0.200	3.400	2.370
228		0.1481	0.1460	0.0021	0.	2.500	1.800	0.200	3.100	2.399
254	0.0839	0.1105	0.1087	0.0018	0.	2.500	1.120	0.240	1.700	2.449

A_{leaf}=0.1775 B_{stalk}=0.0010 C_{soil}=0.5000 D=3.7850 E=0.5576

CORRELATION COEFFICIENT=0.940

1979 CORN C-15
35.6 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
156		0.0580	0.0218	0.	0.0362	0.250	0.	0.140	0.300	0.021
171	0.0608	0.0695	0.0635	0.0003	0.0057	0.610	0.690	0.240	1.000	0.052
178	0.0728	0.0962	0.0950	0.0012	0.	0.810	1.980	0.240	1.700	0.215
192	0.1169	0.1322	0.1297	0.0025	0.	1.960	2.140	0.060	2.800	0.593
201	0.1225	0.1396	0.1368	0.0028	0.	2.480	1.980	0.320	3.100	1.322
213	0.1175	0.1461	0.1431	0.0030	0.	2.500	2.160	0.200	3.400	2.370
228		0.1394	0.1368	0.0026	0.	2.500	1.800	0.200	3.100	2.399
254	0.0977	0.0970	0.0950	0.0020	0.	2.500	1.120	0.240	1.700	2.449

A_{leaf}=0.1925 B_{stalk}=0.0010 C_{soil}=0.2917 D=5.0000 E=0.4000

CORRELATION COEFFICIENT=0.943

MANHATTAN AGRICULTURAL EXPERIMENT

1979 CORN C-16
8.6 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
156		0.0514	0.0142	0.	0.0372	0.250	0.	0.120	0.200	0.010
171	0.0652	0.0780	0.0420	0.0003	0.0357	0.610	0.330	0.260	0.650	0.033
178	0.1005	0.0806	0.0775	0 0016	0.0015	0.810	1.360	0.240	1.400	0.121
192	0.1186	0.1106	0.1070	0.0036	0.	1.960	1.480	0.240	2.300	0.444
201	0.1225	0.1192	0.1145	0.0047	0.	2.480	1.610	0.280	2.600	0.641
213	0.1033	0.1150	0.1096	0.0054	0.	2.500	1.760	0.200	2.400	0.947
228		0.1028	0.0984	0.0044	0.	2.500	1.330	0.200	2.000	1.420
254	0.0778	0.0840	0.0814	0.0018	0.0008	2.500	0.500	0.220	1.500	2.000

A_{leaf}=0.1667 B_{stalk}=0.0020 C_{soil}=0.3388 D=3.0470 E=0.4464

CORRELATION COEFFICIENT=0.826

1979 CORN C-16
13.0 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
156		0.0571	0.0140	0.	0.0431	0.250	0.	0.120	0.200	0.010
171	0.0622	0.0752	0.0404	0.0005	0.0343	0.610	0.330	0.260	0.650	0.033
178	0.0743	0.0753	0.0724	0.0022	0.0007	0.810	1.360	0.240	1.400	0.121
192	0.0912	0.1017	0.0970	0.0048	0.	1.960	1.480	0.240	2.300	0.444
201	0.1079	0.1090	0.1028	0.0061	0.	2.480	1.610	0.280	2.600	0.641
213	0.1023	0.1061	0.0990	0.0071	0.	2.500	1.760	0.200	2.400	0.947
228		0.0959	0.0901	0.0058	0.	2.500	1.330	0.200	2.000	1.420
254	0.0957	0.0785	0.0757	0.0025	0.0003	2.500	0.500	0.220	1.500	2.000

A_{leaf}=0.1360 B_{stalk}=0.0029 C_{soil}=0.4008 D=3.7740 E=0.5426

CORRELATION COEFFICIENT=0.803

MANHATTAN AGRICULTURAL EXPERIMENT

1979 CORN C-16
17.0 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
156		0.0724	0.0187	0.	0.0537	0.250	0.	0.120	0.200	0.010
171	0.0736	0.0964	0.0540	0.0002	0.0422	0.610	0.330	0.260	0.650	0.033
178	0.0826	0.0978	0.0962	0.0008	0.0008	0.810	1.360	0.240	1.400	0.121
192	0.1288	0.1299	0.1283	0.0016	0.	1.960	1.480	0.240	2.300	0.444
201	0.1333	0.1380	0.1359	0.0021	0.	2.480	1.610	0.280	2.600	0.641
213	0.1250	0.1334	0.1310	0.0024	0.	2.500	1.760	0.200	2.400	0.947
228		0.1213	0.1193	0.0020	0.	2.500	1.330	0.200	2.000	1.420
254	0.1213	0.1019	0.1006	0.0008	0.0004	2.500	0.500	0.220	1.500	2.000

A_{leaf}=0.1775 B_{stalk}=0.0010 C_{soil}=0.5000 D=3.7850 E=0.5576

CORRELATION COEFFICIENT=0.832

1979 CORN C-16
35.6 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
156		0.0471	0.0148	0.	0.0323	0.250	0.	0.120	0.200	0.010
171	0.0609	0.0656	0.0441	0.0002	0.0214	0.610	0.330	0.260	0.650	0.033
178	0.0826	0.0836	0.0826	0.0008	0.0002	0.810	1.360	0.240	1.400	0.121
192	0.1175	0.1177	0.1158	0.0019	0.	1.960	1.480	0.240	2.300	0.444
201	0.1202	0.1270	0.1245	0.0025	0.	2.480	1.610	0.280	2.600	0.641
213	0.1148	0.1216	0.1188	0.0028	0.	2.500	1.760	0.200	2.400	0.947
228		0.1083	0.1060	0.0023	0.	2.500	1.330	0.200	2.000	1.420
254	0.1000	0.0879	0.0869	0.0009	0.0001	2.500	0.500	0.220	1.500	2.000

A_{leaf}=0.1925 B_{stalk}=0.0010 C_{soil}=0.2917 D=5.0000 E=0.4000

CORRELATION COEFFICIENT=0.959

MANHATTAN AGRICULTURAL EXPERIMENT

1979 CORN C-11
8.6 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
156	0.0579	0.0602	0.0299	0.	0.0303	0.250	0.300	0.140	0.400	0.037
169	0.0570	0.0825	0.0808	0.	0.0016	0.520	0.960	0.200	1.400	0.130
177	0.1109	0.1002	0.1001	0.0001	0.	0.800	1.630	0.320	2.000	0.225
191	0.1400	0.1329	0.1327	0.0001	0.	1.810	2.070	0.360	4.010	0.624
200	0.1585	0.1400	0.1398	0.0002	0.	2.500	2.440	0.320	5.100	0.805
204	0.1412	0.1401	0.1398	0.0002	0.	2.650	2.540	0.300	5.100	0.885
207	0.1690	0.1401	0.1398	0.0002	0.	2.750	2.640	0.300	5.100	0.946
208	0.1465	0.1401	0.1398	0.0002	0.	2.710	2.750	0.300	5.100	0.966
212	0.1321	0.1391	0.1388	0.0003	0.	2.650	2.800	0.280	4.900	1.046
226		0.1416	0.1414	0.0002	0.	2.500	2.560	0.220	5.470	1.328
228		0.1412	0.1410	0.0002	0.	2.500	2.520	0.200	5.352	1.841
242	0.0925	0.1210	0.1208	0.0002	0.	2.500	1.640	0.180	3.000	2.598

A_{leaf}=0.1482 B_{stalk}=0.0001 C_{soil}=0.4381 D=6.3990 E=0.5268

CORRELATION COEFFICIENT=0.912

1979 CORN C-11
13.0 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
156	0.0537	0.0602	0.0363	0.	0.0239	0.250	0.300	0.140	0.400	0.037
169	0.0927	0.0850	0.0829	0.	0.0021	0.520	0.960	0.200	1.400	0.130
177	0.1109	0.0952	0.0951	0.0001	0.0001	0.800	1.630	0.320	2.000	0.225
191	0.1245	0.1080	0.1079	0.0001	0.	1.810	2.070	0.360	4.010	0.624
200	0.1230	0.1094	0.1093	0.0001	0.	2.500	2.440	0.320	5.100	0.805
204	0.1094	0.1094	0.1093	0.0001	0.	2.650	2.540	0.300	5.100	0.885
207	0.1159	0.1094	0.1093	0.0001	0.	2.750	2.640	0.300	5.100	0.946
208	0.1096	0.1094	0.1093	0.0001	0.	2.710	2.750	0.300	5.100	0.966
212	0.1021	0.1093	0.1091	0.0002	0.	2.650	2.800	0.280	4.900	1.046
226		0.1096	0.1095	0.0001	0.	2.500	2.560	0.220	5.470	1.328
228		0.1095	0.1094	0.0001	0.	2.500	2.520	0.200	5.352	1.841
242	0.0957	0.1046	0.1045	0.0001	0.	2.500	1.640	0.180	3.000	2.598

A_{leaf}=0.1100 B_{stalk}=0.0001 C_{soil}=0.3497 D=4.2280 E=1.0020

CORRELATION COEFFICIENT=0.887

MANHATTAN AGRICULTURAL EXPERIMENT

1979 CORN C-11
17.0 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
156	0.0851	0.0785	0.0360	0.	0.0425	0.250	0.300	0.140	0.400	0.037
169	0.0809	0.0941	0.0928	0.	0.0013	0.520	0.960	0.200	1.400	0.130
177	0.1303	0.1123	0.1122	0.0001	0.	0.800	1.630	0.320	2.000	0.225
191	0.1901	0.1411	0.1410	0.0001	0.	1.810	2.070	0.360	4.010	0.624
200	0.1862	0.1463	0.1461	0.0002	0.	2.500	2.440	0.320	5.100	0.805
204	0.1841	0.1463	0.1461	0.0002	0.	2.650	2.540	0.300	5.100	0.885
207	0.1618	0.1463	0.1461	0.0002	0.	2.750	2.640	0.300	5.100	0.946
208	0.1463	0.1463	0.1461	0.0002	0.	2.710	2.750	0.300	5.100	0.966
212	0.1660	0.1456	0.1454	0.0002	0.	2.650	2.800	0.280	4.900	1.046
226		0.1473	0.1471	0.0002	0.	2.500	2.560	0.220	5.470	1.328
228		0.1470	0.1468	0.0002	0.	2.500	2.520	0.200	5.352	1.841
242	0.1855	0.1315	0.1313	0.0002	0.	2.500	1.640	0.180	3.000	2.598

A_{leaf}=0.1508 B_{stalk}=0.0001 C_{soil}=0.7000 D=7.4920 E=0.6820

CORRELATION COEFFICIENT=0.805

1979 CORN C-11
35.6 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
156	0.0728	0.0646	0.0240	0.	0.0405	0.250	0.300	0.140	0.400	0.037
169		0.0721	0.0714	0.	0.0006	0.520	0.960	0.200	1.400	0.130
177	0.1151	0.0931	0.0930	0.0001	0.	0.800	1.630	0.320	2.000	0.225
191	0.1742	0.1401	0.1399	0.0002	0.	1.810	2.070	0.360	4.010	0.624
200	0.1774	0.1549	0.1546	0.0003	0.	2.500	2.440	0.320	5.100	0.805
204	0.1849	0.1549	0.1546	0.0003	0.	2.650	2.540	0.300	5.100	0.885
207	0.1738	0.1550	0.1546	0.0003	0.	2.750	2.640	0.300	5.100	0.946
208	0.1698	0.1550	0.1546	0.0004	0.	2.710	2.750	0.300	5.100	0.966
212	0.1432	0.1527	0.1523	0.0004	0.	2.650	2.800	0.280	4.900	1.046
226		0.1588	0.1585	0.0003	0.	2.500	2.560	0.220	5.470	1.328
228		0.1576	0.1573	0.0003	0.	2.500	2.520	0.200	5.352	1.841
242	0.1230	0.1206	0.1203	0.0003	0.	2.500	1.640	0.180	3.000	2.598

A_{leaf}=0.1871 B_{stalk}=0.0001 C_{soil}=0.7000 D=9.9370 E=0.3435

CORRELATION COEFFICIENT=0.934

MANHATTAN AGRICULTURAL EXPERIMENT

1979 CORN C-12
8.6 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
156		0.0748	0.0230	0.	0.0518	0.250	0.	0.140	0.300	0.024
169	0.0484	0.0450	0.0364	0.	0.0086	0.520	0.580	0.180	0.500	0.040
177	0.0851	0.0770	0.0769	0.0001	0.	0.800	1.500	0.320	1.300	0.122
191	0.1549	0.1226	0.1223	0.0002	0.	1.810	2.540	0.320	3.100	0.415
200	0.1510	0.1278	0.1276	0.0003	0.	2.500	2.400	0.300	3.500	0.814
212	0.1107	0.1301	0.1298	0.0003	0.	2.560	3.090	0.280	3.700	1.346
228		0.1345	0.1343	0.0002	0.	2.500	2.440	0.200	4.200	2.000
242	0.0925	0.1122	0.1119	0.0002	0.	2.500	1.800	0.180	2.500	2.583

A_{leaf}=0.1482 B_{stalk}=0.0001 C_{soil}=0.4381 D=6.3990 E=0.5268

CORRELATION COEFFICIENT=0.852

1979 CORN C-12
13.0 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
156		0.0648	0.0285	0.	0.0362	0.250	0.	0.140	0.300	0.024
169	0.0682	0.0540	0.0433	0.	0.0107	0.520	0.580	0.180	0.500	0.040
177	0.0912	0.0803	0.0800	0.0001	0.0002	0.800	1.500	0.320	1.300	0.122
191	0.1259	0.1051	0.1050	0.0001	0.	1.810	2.540	0.320	3.100	0.415
200	0.1324	0.1068	0.1066	0.0002	0.	2.500	2.400	0.300	3.500	0.814
212	0.0929	0.1074	0.1072	0.0002	0.	2.560	3.090	0.280	3.700	1.346
228		0.1084	0.1083	0.0001	0.	2.500	2.440	0.200	4.200	2.000
242	0.0957	0.1011	0.1009	0.0002	0.	2.500	1.800	0.180	2.500	2.583

A_{leaf}=0.1100 B_{stalk}=0.0001 C_{soil}=0.3497 D=4.2280 E=1.0020

CORRELATION COEFFICIENT=0.771

MANHATTAN AGRICULTURAL EXPERIMENT

1979 CORN C-12
17.0 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
156		0.1078	0.0279	0.	0.0799	0.250	0.	0.140	0.300	0.024
169	0.0728	0.0530	0.0436	0.	0.0094	0.520	0.580	0.180	0.500	0.040
177	0.0993	0.0888	0.0887	0.0001	0.	0.800	1.500	0.320	1.300	0.122
191	0.1618	0.1328	0.1326	0.0002	0.	1.810	2.540	0.320	3.100	0.415
200	0.1493	0.1371	0.1369	0.0002	0.	2.500	2.400	0.300	3.500	0.814
212	0.1169	0.1390	0.1387	0.0003	0.	2.560	3.090	0.280	3.700	1.346
228		0.1424	0.1422	0.0002	0.	2.500	2.440	0.200	4.200	2.000
242	0.0855	0.1236	0.1234	0.0002	0.	2.500	1.800	0.180	2.500	2.583

A_{leaf}=0.1508 B_{stalk}=0.0001 C_{soil}=0.7000 D=7.4920 E=0.6820

CORRELATION COEFFICIENT=0.721

1979 CORN C-12
35.6 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
156		0.1067	0.0183	0.	0.0884	0.250	0.	0.140	0.300	0.024
169		0.0348	0.0295	0.	0.0053	0.520	0.580	0.180	0.500	0.040
177	0.0813	0.0675	0.0674	0.0001	0.	0.800	1.500	0.320	1.300	0.122
191	0.1479	0.1229	0.1226	0.0003	0.	1.810	2.540	0.320	3.100	0.415
200	0.1200	0.1312	0.1308	0.0003	0.	2.500	2.400	0.300	3.500	0.814
212	0.1122	0.1350	0.1346	0.0004	0.	2.560	3.090	0.280	3.700	1.346
228		0.1432	0.1429	0.0003	0.	2.500	2.440	0.200	4.200	2.000
242	0.1380	0.1081	0.1078	0.0003	0.	2.500	1.800	0.180	2.500	2.583

A_{leaf}=0.1871 B_{stalk}=0.0001 C_{soil}=0.7000 D=9.9370 E=0.3435

CORRELATION COEFFICIENT=0.627

MANHATTAN AGRICULTURAL EXPERIMENT

1979 CORN C-13
8.6 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
156		0.0661	0.0081	0.	0.0580	0.250	0.	0.140	0.100	0.009
169	0.0587	0.0398	0.0230	0.	0.0167	0.520	0.380	0.160	0.300	0.027
177	0.0857	0.0770	0.0769	0.0001	0.	0.800	1.630	0.320	1.300	0.128
191	0.1256	0.1004	0.1001	0.0002	0.	1.810	1.880	0.300	2.000	0.266
200	0.1200	0.1031	0.1028	0.0003	0.	2.500	1.960	0.300	2.100	0.539
212	0.1172	0.1142	0.1139	0.0003	0.	2.560	2.200	0.240	2.600	0.902
228		0.1161	0.1158	0.0003	0.	2.500	2.040	0.200	2.700	1.234
247	0.0818	0.0847	0.0845	0.0002	0.	2.500	1.240	0.120	1.500	1.580

A_{leaf}=0.1482 B_{stalk}=0.0001 C_{soil}=0.4381 D=6.3990 E=0.5268

CORRELATION COEFFICIENT=0.921

1979 CORN C-13
13.0 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
156		0.0548	0.0105	0.	0.0443	0.250	0.	0.140	0.100	0.009
169	0.0815	0.0465	0.0285	0.	0.0180	0.520	0.380	0.160	0.300	0.027
177	0.0933	0.0802	0.0800	0.0001	0.0001	0.800	1.630	0.320	1.300	0.128
191	0.1200	0.0953	0.0951	0.0001	0.	1.810	1.880	0.300	2.000	0.266
200	0.0891	0.0967	0.0965	0.0002	0.	2.500	1.960	0.300	2.100	0.539
212	0.1047	0.1020	0.1018	0.0002	0.	2.560	2.200	0.240	2.600	0.902
228		0.1028	0.1026	0.0002	0.	2.500	2.040	0.200	2.700	1.234
247	0.0807	0.0856	0.0855	0.0002	0.	2.500	1.240	0.120	1.500	1.580

A_{leaf}=0.1100 B_{stalk}=0.0001 C_{soil}=0.3497 D=4.2280 E=1.0020

CORRELATION COEFFICIENT=0.572

MANHATTAN AGRICULTURAL EXPERIMENT

1979 CORN C-13
17.0 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
156		0.1015	0.0099	0.	0.0915	0.250	0.	0.140	0.100	0.009
169	0.0646	0.0487	0.0279	0.	0.0208	0.520	0.380	0.160	0.300	0.027
177	0.1023	0.0888	0.0887	0.0001	0.	0.800	1.630	0.320	1.300	0.128
191	0.1578	0.1124	0.1122	0.0002	0.	1.810	1.880	0.300	2.000	0.266
200	0.1377	0.1150	0.1148	0.0003	0.	2.500	1.960	0.300	2.100	0.539
212	0.1119	0.1254	0.1252	0.0003	0.	2.560	2.200	0.240	2.600	0.902
228		0.1271	0.1269	0.0002	0.	2.500	2.040	0.200	2.700	1.234
247	0.1119	0.0968	0.0966	0.0002	0.	2.500	1.240	0.120	1.500	1.580

A_{leaf}=0.1508 B_{stalk}=0.0001 C_{soil}=0.7000 D=7.4920 E=0.6820

CORRELATION COEFFICIENT=0.807

1979 CORN C-13
35.6 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
156		0.1010	0.0063	0.	0.0947	0.250	0.	0.140	0.100	0.009
169		0.0325	0.0183	0.	0.0142	0.520	0.380	0.160	0.300	0.027
177	0.0646	0.0675	0.0674	0.0001	0.	0.800	1.630	0.320	1.300	0.128
191	0.1099	0.0932	0.0930	0.0002	0.	1.810	1.880	0.300	2.000	0.266
200	0.1023	0.0965	0.0961	0.0003	0.	2.500	1.960	0.300	2.100	0.539
212	0.0871	0.1109	0.1105	0.0004	0.	2.560	2.200	0.240	2.600	0.902
228		0.1134	0.1131	0.0003	0.	2.500	2.040	0.200	2.700	1.234
247	0.1000	0.0756	0.0753	0.0002	0.	2.500	1.240	0.120	1.500	1.580

A_{leaf}=0.1871 B_{stalk}=0.0001 C_{soil}=0.7000 D=9.9370 E=0.3435

CORRELATION COEFFICIENT=0.431

MANHATTAN AGRICULTURAL EXPERIMENT

1979 CORN C-14
8.6 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
156		0.0827	0.0364	0.	0.0463	0.250	0.	0.140	0.500	0.045
171	0.0721	0.0813	0.0808	0.	0.0004	0.610	0.980	0.100	1.400	0.094
178	0.0953	0.1017	0.1015	0.0002	0.	0.810	3.580	0.240	2.050	0.118
192	0.1119	0.1353	0.1351	0.0003	0.	1.960	3.780	0.280	4.300	0.930
201	0.1321	0.1406	0.1403	0.0003	0.	2.480	3.870	0.300	5.200	1.429
213	0.1306	0.1397	0.1394	0.0003	0.	2.500	3.650	0.200	5.000	1.574
228		0.1436	0.1435	0.0002	0.	2.500	2.600	0.200	6.100	1.699
247	0.1049	0.1195	0.1193	0.0003	0.	2.500	2.080	0.120	2.900	1.825

A_{leaf}=0.1482 B_{stalk}=0.0001 C_{soil}=0.4381 D=6.3990 E=0.5268

CORRELATION COEFFICIENT=0.965

1979 CORN C-14
13.0 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
156		0.0730	0.0433	0.	0.0297	0.250	0.	0.140	0.500	0.045
171	0.0759	0.0836	0.0829	0.	0.0007	0.610	0.980	0.100	1.400	0.094
178	0.0832	0.0960	0.0958	0.0001	0.	0.810	3.580	0.240	2.050	0.118
192	0.0977	0.1086	0.1084	0.0002	0.	1.960	3.780	0.280	4.300	0.930
201	0.1084	0.1095	0.1093	0.0002	0.	2.480	3.870	0.300	5.200	1.429
213	0.1037	0.1094	0.1092	0.0002	0.	2.500	3.650	0.200	5.000	1.574
228		0.1098	0.1097	0.0001	0.	2.500	2.600	0.200	6.100	1.699
247	0.0706	0.1041	0.1039	0.0002	0.	2.500	2.080	0.120	2.900	1.825

A_{leaf}=0.1100 B_{stalk}=0.0001 C_{soil}=0.3497 D=4.2280 E=1.0020

CORRELATION COEFFICIENT=0.687

MANHATTAN AGRICULTURAL EXPERIMENT

1979 CORN C-14
17.0 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
156		0.1132	0.0436	0.	0.0697	0.250	0.	0.140	0.500	0.045
171	0.0724	0.0931	0.0928	0.	0.0003	0.610	0.980	0.100	1.400	0.094
178	0.1230	0.1137	0.1135	0.0002	0.	0.810	3.580	0.240	2.050	0.118
192	0.1288	0.1430	0.1427	0.0002	0.	1.960	3.780	0.280	4.300	0.930
201	0.1169	0.1467	0.1464	0.0003	0.	2.480	3.870	0.300	5.200	1.429
213	0.1107	0.1460	0.1458	0.0003	0.	2.500	3.650	0.200	5.000	1.574
228		0.1486	0.1484	0.0002	0.	2.500	2.600	0.200	6.100	1.699
247	0.1125	0.1301	0.1299	0.0002	0.	2.500	2.080	0.120	2.900	1.825

A_{leaf}=0.1508 B_{stalk}=0.0001 C_{soil}=0.7000 D=7.4920 E=0.6820

CORRELATION COEFFICIENT=0.721

1979 CORN C-14
35.6 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
156		0.1121	0.0295	0.	0.0825	0.250	0.	0.140	0.500	0.045
171	0.0690	0.0716	0.0714	0.	0.0001	0.610	0.980	0.100	1.400	0.094
178	0.0953	0.0948	0.0946	0.0002	0.	0.810	3.580	0.240	2.050	0.118
192	0.1151	0.1447	0.1444	0.0004	0.	1.960	3.780	0.280	4.300	0.930
201	0.1380	0.1562	0.1557	0.0004	0.	2.480	3.870	0.300	5.200	1.429
213	0.1276	0.1539	0.1535	0.0004	0.	2.500	3.650	0.200	5.000	1.574
228		0.1643	0.1640	0.0003	0.	2.500	2.600	0.200	6.100	1.699
247	0.0912	0.1183	0.1180	0.0003	0.	2.500	2.080	0.120	2.900	1.825

A_{leaf}=0.1871 B_{stalk}=0.0001 C_{soil}=0.7000 D=9.9370 E=0.3435

CORRELATION COEFFICIENT=0.948

MANHATTAN AGRICULTURAL EXPERIMENT

1979 CORN C-15
8.6 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
156		0.0748	0.0230	0.	0.0518	0.250	0.	0.140	0.300	0.021
171	0.0644	0.0679	0.0638	0.	0.0041	0.610	0.690	0.240	1.000	0.052
178	0.0824	0.0914	0.0913	0.0001	0.	0.810	1.980	0.240	1.700	0.215
192	0.1069	0.1178	0.1176	0.0002	0.	1.960	2.140	0.060	2.800	0.593
201	0.1167	0.1226	0.1223	0.0002	0.	2.480	1.980	0.320	3.100	1.322
213	0.1200	0.1266	0.1264	0.0002	0.	2.500	2.160	0.200	3.400	2.370
228		0.1226	0.1223	0.0002	0.	2.500	1.800	0.200	3.100	2.399
254	0.1175	0.0915	0.0913	0.0002	0.	2.500	1.120	0.240	1.700	2.449

A_{leaf}=0.1482 B_{stalk}=0.0001 C_{soil}=0.4381 D=6.3990 E=0.5268

CORRELATION COEFFICIENT=0.819

1979 CORN C-15
13.0 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
156		0.0648	0.0285	0.	0.0362	0.250	0.	0.140	0.300	0.021
171	0.0507	0.0748	0.0696	0.	0.0052	0.610	0.690	0.240	1.000	0.052
178	0.0741	0.0900	0.0899	0.0001	0.	0.810	1.980	0.240	1.700	0.215
192	0.1049	0.1034	0.1033	0.0001	0.	1.960	2.140	0.060	2.800	0.593
201	0.1089	0.1052	0.1050	0.0002	0.	2.480	1.980	0.320	3.100	1.322
213	0.1000	0.1064	0.1063	0.0002	0.	2.500	2.160	0.200	3.400	2.370
228		0.1051	0.1050	0.0001	0.	2.500	1.800	0.200	3.100	2.399
254	0.0914	0.0900	0.0899	0.0001	0.	2.500	1.120	0.240	1.700	2.449

A_{leaf}=0.1100 B_{stalk}=0.0001 C_{soil}=0.3497 D=4.2280 E=1.0020

CORRELATION COEFFICIENT=0.947

MANHATTAN AGRICULTURAL EXPERIMENT

1979 CORN C-15
17.0 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
156		0.1078	0.0279	0.	0.0799	0.250	0.	0.140	0.300	0.021
171	0.0662	0.0782	0.0746	0.	0.0036	0.610	0.690	0.240	1.000	0.052
178	0.1042	0.1036	0.1035	0.0001	0.	0.810	1.980	0.240	1.700	0.215
192	0.0973	0.1286	0.1284	0.0002	0.	1.960	2.140	0.060	2.800	0.593
201	0.1062	0.1328	0.1326	0.0002	0.	2.480	1.980	0.320	3.100	1.322
213	0.1114	0.1361	0.1359	0.0002	0.	2.500	2.160	0.200	3.400	2.370
228		0.1328	0.1326	0.0002	0.	2.500	1.800	0.200	3.100	2.399
254	0.1151	0.1037	0.1035	0.0002	0.	2.500	1.120	0.240	1.700	2.449

A_{leaf}=0.1508 B_{stalk}=0.0001 C_{soil}=0.7000 D=7.4920 E=0.6820

CORRELATION COEFFICIENT=0.670

1979 CORN C-15
35.6 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
156		0.1067	0.0183	0.	0.0884	0.250	0.	0.140	0.300	0.021
171	0.0537	0.0562	0.0544	0.	0.0018	0.610	0.690	0.240	1.000	0.052
178	0.0685	0.0829	0.0827	0.0001	0.	0.810	1.980	0.240	1.700	0.215
192	0.1102	0.1158	0.1156	0.0003	0.	1.960	2.140	0.060	2.800	0.593
201	0.1140	0.1229	0.1226	0.0003	0.	2.480	1.980	0.320	3.100	1.322
213	0.1014	0.1292	0.1289	0.0003	0.	2.500	2.160	0.200	3.400	2.370
228		0.1228	0.1226	0.0003	0.	2.500	1.800	0.200	3.100	2.399
254	0.0603	0.0830	0.0827	0.0002	0.	2.500	1.120	0.240	1.700	2.449

A_{leaf}=0.1871 B_{stalk}=0.0001 C_{soil}=0.7000 D=9.9370 E=0.3435

CORRELATION COEFFICIENT=0.938

MANHATTAN AGRICULTURAL EXPERIMENT

1979 CORN C-16
8.6 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
156		0.0628	0.0158	0.	0.0470	0.250	0.	0.120	0.200	0.010
171	0.0585	0.0672	0.0454	0.	0.0218	0.610	0.330	0.260	0.650	0.033
178	0.0822	0.0809	0.0808	0.0001	0.	0.810	1.360	0.240	1.400	0.121
192	0.1107	0.1078	0.1076	0.0002	0.	1.960	1.480	0.240	2.300	0.444
201	0.1096	0.1141	0.1139	0.0002	0.	2.480	1.610	0.280	2.600	0.641
213	0.0955	0.1101	0.1098	0.0002	0.	2.500	1.760	0.200	2.400	0.947
228		0.1003	0.1001	0.0002	0.	2.500	1.330	0.200	2.000	1.420
254	0.0933	0.0846	0.0845	0.0001	0.	2.500	0.500	0.220	1.500	2.000

A_{leaf}=0.1482 B_{stalk}=0.0001 C_{soil}=0.4381 D=6.3990 E=0.5268

CORRELATION COEFFICIENT=0.904

1979 CORN C-16
13.0 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
156		0.0543	0.0200	0.	0.0343	0.250	0.	0.120	0.200	0.010
171	0.0436	0.0729	0.0526	0.	0.0202	0.610	0.330	0.260	0.650	0.033
178	0.0805	0.0832	0.0829	0.0001	0.0002	0.810	1.360	0.240	1.400	0.121
192	0.1000	0.0991	0.0990	0.0001	0.	1.960	1.480	0.240	2.300	0.444
201	0.0995	0.1019	0.1018	0.0001	0.	2.480	1.610	0.280	2.600	0.641
213	0.1000	0.1002	0.1000	0.0002	0.	2.500	1.760	0.200	2.400	0.947
228		0.0953	0.0951	0.0001	0.	2.500	1.330	0.200	2.000	1.420
254	0.0891	0.0856	0.0855	0.0001	0.0001	2.500	0.500	0.220	1.500	2.000

A_{leaf}=0.1100 B_{stalk}=0.0001 C_{soil}=0.3497 D=4.2280 E=1.0020

CORRELATION COEFFICIENT=0.919

MANHATTAN AGRICULTURAL EXPERIMENT

1979 CORN C-16
17.0 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
156		0.0925	0.0192	0.	0.0733	0.250	0.	0.120	0.200	0.010
171	0.0573	0.0799	0.0540	0.	0.0259	0.610	0.330	0.260	0.650	0.033
178	0.0841	0.0928	0.0928	0.0001	0.	0.810	1.360	0.240	1.400	0.121
192	0.1230	0.1195	0.1194	0.0001	0.	1.960	1.480	0.240	2.300	0.444
201	0.1148	0.1254	0.1252	0.0002	0.	2.480	1.610	0.280	2.600	0.641
213	0.0923	0.1217	0.1214	0.0002	0.	2.500	1.760	0.200	2.400	0.947
228		0.1124	0.1122	0.0002	0.	2.500	1.330	0.200	2.000	1.420
254	0.1169	0.0967	0.0966	0.0001	0.	2.500	0.500	0.220	1.500	2.000

A_{leaf}=0.1508 B_{stalk}=0.0001 C_{soil}=0.7000 D=7.4920 E=0.6820

CORRELATION COEFFICIENT=0.700

1979 CORN C-16
35.6 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
156		0.0908	0.0124	0.	0.0784	0.250	0.	0.120	0.200	0.010
171	0.0513	0.0571	0.0374	0.	0.0197	0.610	0.330	0.260	0.650	0.033
178	0.0690	0.0715	0.0714	0.0001	0.	0.810	1.360	0.240	1.400	0.121
192	0.1084	0.1024	0.1022	0.0002	0.	1.960	1.480	0.240	2.300	0.444
201	0.1071	0.1107	0.1105	0.0003	0.	2.480	1.610	0.280	2.600	0.641
213	0.1014	0.1053	0.1050	0.0003	0.	2.500	1.760	0.200	2.400	0.947
228		0.0932	0.0930	0.0002	0.	2.500	1.330	0.200	2.000	1.420
254	0.0832	0.0754	0.0753	0.0001	0	2.500	0.500	0.220	1.500	2.000

A_{leaf}=0.1871 B_{stalk}=0.0001 C_{soil}=0.7000 D=9.9370 E=0.3435

CORRELATION COEFFICIENT=0.969

APPENDIX D - 1980 Sorghum Data

Observed values of the backscattering coefficients, predicted values, ground-truth values, and correlation between predicted and observed backscattering coefficients, and model values for three intensively measured sorghum fields.

MODEL EQUATION

$$\sigma^{o}_{pred} = \sigma^{o}_{leaf} + \sigma^{o}_{stalk} + \sigma^{o}_{soil}$$

$$= A_{leaf}\,(1 - e^{-E \cdot LAI})$$

$$+ \frac{B_{stalk} \cdot W \cdot H}{E \cdot LAI}\,(1 - e^{-E \cdot LAI})$$

$$\cdot\, e^{-D \cdot W \cdot H}\, e^{E \cdot LAI}$$

$$+ C_{soil} \cdot m_s$$

Symbol	SI Units	Description
σ^{o}_{pred}	$m^2\ m^{-2}$	Predicted backscattering cross section coefficient
σ^{o}_{leaf}	$m^2\ m^{-2}$	Backscattering cross section coefficient for leaf contribution
σ^{o}_{stalk}	$m^2\ m^{-2}$	Backscattering cross section coefficient for stalk contribution
σ^{o}_{soil}	$m^2\ m^{-2}$	Backscattering cross section coefficient for soil contribution
LAI	$m^2\ m^{-2}$	Leaf Area Index
H	m	crop canopy height
W	$kg\ m^{-3}$	Volumetric normalized plant water content
m_s	$kg\ m^{-3}$	Volumetric soil moisture content
A_{leaf}	----	Empirical coefficient for leaf contribution to predicted radar backscatter
B_{stalk}	----	Empirical coefficient for stalk contribution to predicted radar backscatter
C_{soil}	----	Empirical coefficient for soil contribution to predicted radar backscatter
D	nepers $m\ kg^{-1}$	Empirical attenuation coefficient for attenuation due to plant water
E	nepers	Empirical attenuation constant for attenuation due to leaves
ρ	----	Correlation coefficient between predicted and observed backscatter coefficients

MANHATTAN AGRICULTURAL EXPERIMENT

1980 SORGHUM S-31
8.6 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
158	0.0631	0.0575	0.0095	0.	0.0480	0.102	0.005	0.268	0.070	0.009
161	0.0389	0.0469	0.0120	0.0008	0.0341	0.198	0.079	0.212	0.090	0.010
165		0.0365	0.0156	0.0038	0.0171	0.356	0.218	0.151	0.120	0.017
168	0.0562	0.0558	0.0413	0.0068	0.0077	0.486	0.349	0.160	0.382	0.027
170	0.0708	0.0693	0.0595	0.0086	0.0012	0.574	0.448	0.057	0.659	0.037
171		0.0764	0.0662	0.0095	0.0007	0.617	0.500	0.054	0.801	0.044
176	0.0933	0.0983	0.0844	0.0137	0.0002	0.821	0.788	0.257	1.485	0.088
178	0.0977	0.1029	0.0875	0.0153	0.	0.890	0.913	0.191	1.725	0.120
182	0.1164	0.1085	0.0922	0.0163	0.	0.996	1.175	0.074	2.456	0.194
189		0.1110	0.0940	0.0169	0.	1.024	1.657	0.109	3.509	0.353
190	0.1175	0.1111	0.0941	0.0170	0.	1.027	1.727	0.082	3.649	0.379
192	0.1371	0.1115	0.0943	0.0172	0.	1.031	1.865	0.056	3.920	0.431
196	0.1148	0.1121	0.0944	0.0177	0.	1.039	2.137	0.041	4.409	0.539
198	0.1084	0.1124	0.0944	0.0180	0.	1.043	2.269	0.033	4.623	0.594
199		0.1126	0.0944	0.0181	0.	1.044	2.333	0.037	4.721	0.624
204	0.1208	0.1135	0.0945	0.0190	0.	1.050	2.636	0.179	5.122	0.767
206	0.1112	0.1139	0.0945	0.0194	0.	1.052	2.747	0.115	5.226	0.825
210	0.1143	0.1147	0.0945	0.0203	0.	1.053	2.945	0.077	5.382	0.938
212		0.1152	0.0945	0.0207	0.	1.053	3.030	0.065	5.413	0.894
213	0.1291	0.1155	0.0945	0.0210	0.	1.053	3.070	0.054	5.417	1.021
217		0.1165	0.0945	0.0220	0.	1.051	3.199	0.043	5.368	1.125
218		0.1168	0.0945	0.0223	0.	1.051	3.225	0.217	5.338	1.150
220		0.1174	0.0945	0.0229	0.	1.049	3.266	0.059	5.260	1.198
221	0.1033	0.1177	0.0945	0.0232	0.	1.048	3.281	0.111	5.211	1.221
224		0.1186	0.0945	0.0241	0.	1.044	3.306	0.108	5.029	1.287
225	0.1076	0.1189	0.0945	0.0245	0.	1.042	3.308	0.082	4.957	1.307
231	0.1132	0.1208	0.0944	0.0264	0.	1.030	3.229	0.298	4.421	1.409
240	0.1227	0.1229	0.0939	0.0289	0.	1.005	2.800	0.063	3.402	1.413
247	0.1143	0.1207	0.0926	0.0281	0.	0.978	2.165	0.157	2.602	1.400
254	0.1007	0.1093	0.0898	0.0194	0.	0.946	1.226	0.103	1.995	1.385
268		0.1025	0.0891	0.0133	0.	0.956	0.800	0.162	1.900	1.370

A_{leaf}=0.0945 B_{stalk}=0.0530 C_{soil}=0.1995 D=5.0000 E=1.5067

CORRELATION COEFFICIENT=0.9308

MANHATTAN AGRICULTURAL EXPERIMENT

1980 SORGHUM S-31
13.0 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
158	0.0664	0.0603	0.0110	0.	0.0493	0.102	0.005	0.268	0.070	0.009
161	0.0389	0.0498	0.0140	0.0007	0.0351	0.198	0.079	0.212	0.090	0.010
165		0.0392	0.0183	0.0032	0.0177	0.356	0.218	0.151	0.120	0.017
168	0.0724	0.0637	0.0494	0.0060	0.0083	0.486	0.349	0.160	0.382	0.027
170	0.0957	0.0815	0.0725	0.0077	0.00[illegible]	0.574	0.448	0.057	0.659	0.037
171		0.0907	0.0813	0.0086	0.00[illegible]	0.617	0.500	0.054	0.801	0.044
176	0.1040	0.1199	0.1069	0.0127	0.0003	0.821	0.788	0.257	1.485	0.088
178	0.1211	0.1260	0.1116	0.0143	0.0001	0.890	0.913	0.191	1.725	0.120
182	0.1517	0.1349	0.1194	0.0155	0.	0.996	1.175	0.074	2.456	0.194
189		0.1392	0.1229	0.0162	0.	1.024	1.657	0.109	3.509	0.353
190	0.1412	0.1394	0.1231	0.0163	0.	1.027	1.727	0.082	3.649	0.379
192	0.1412	0.1399	0.1234	0.0165	0.	1.031	1.865	0.056	3.920	0.431
196	0.1648	0.1408	0.1238	0.0170	0.	1.039	2.137	0.041	4.409	0.539
198	0.1393	0.1411	0.1238	0.0173	0.	1.043	2.269	0.033	4.623	0.594
199		0.1413	0.1239	0.0174	0.	1.044	2.333	0.037	4.721	0.624
204	0.1514	0.1422	0.1240	0.0183	0.	1.050	2.636	0.179	5.122	0.767
206	0.1426	0.1427	0.1240	0.0187	0.	1.052	2.747	0.115	5.226	0.825
210	0.1542	0.1435	0.1240	0.0195	0.	1.053	2.945	0.077	5.382	0.938
212		0.1440	0.1240	0.0199	0.	1.053	3.030	0.065	5.413	0.894
213	0.1455	0.1442	0.1240	0.0202	0.	1.053	3.070	0.054	5.417	1.021
217		0.1452	0.1240	0.0212	0.	1.051	3.199	0.043	5.368	1.125
218		0.1455	0.1240	0.0215	0.	1.051	3.225	0.217	5.338	1.150
220		0.1460	0.1240	0.0220	0.	1.049	3.266	0.059	5.260	1.198
221	0.1349	0.1463	0.1240	0.0223	0.	1.048	3.281	0.111	5.211	1.221
224		0.1471	0.1240	0.0232	0.	1.044	3.306	0.108	5.029	1.287
225	0.1202	0.1474	0.1239	0.0235	0.	1.042	3.308	0.082	4.957	1.307
231	0.1622	0.1492	0.1238	0.0254	0.	1.030	3.229	0.298	4.421	1.409
240	0.1496	0.1504	0.1228	0.0277	0.	1.005	2.800	0.063	3.402	1.413
247	0.1432	0.1469	0.1202	0.0267	0.	0.978	2.165	0.157	2.602	1.400
254	0.1069	0.1337	0.1154	0.0183	0.	0.946	1.226	0.103	1.995	1.385
268		0.1268	0.1142	0.0125	0.0001	0.956	0.800	0.162	1.900	1.370

A_{leaf}=0.1214 B_{stalk}=0.0450 C_{soil}=0.2022 D=5.0000 E=1.3300

CORRELATION COEFFICIENT=0.9199

MANHATTAN AGRICULTURAL EXPERIMENT

1980 SORGHUM S-31
17.0 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
158	0.0398	0.0489	0.0142	0.	0.0348	0.102	0.005	0.268	0.070	0.009
161	0.0562	0.0431	0.0179	0.0005	0.0247	0.198	0.079	0.212	0.090	0.010
165		0.0380	0.0234	0.0022	0.0124	0.356	0.218	0.151	0.120	0.017
168	0.0692	0.0718	0.0622	0.0040	0.0056	0.486	0.349	0.160	0.382	0.027
170	0.1091	0.0958	0.0899	0.0051	0.0009	0.574	0.448	0.057	0.659	0.037
171		0.1063	0.1002	0.0056	0.0005	0.617	0.500	0.054	0.801	0.044
176	0.1197	0.1369	0.1286	0.0082	0.0002	0.821	0.788	0.257	1.485	0.088
178	0.1371	0.1426	0.1334	0.0092	0.	0.890	0.913	0.191	1.725	0.120
182	0.1435	0.1508	0.1410	0.0098	0.	0.996	1.175	0.074	2.456	0.194
189		0.1543	0.1441	0.0102	0.	1.024	1.657	0.109	3.509	0.353
190	0.1493	0.1545	0.1443	0.0102	0.	1.027	1.727	0.082	3.649	0.379
192	0.1698	0.1549	0.1445	0.0103	0.	1.031	1.865	0.056	3.920	0.431
196	0.1648	0.1554	0.1448	0.0106	0.	1.039	2.137	0.041	4.409	0.539
198	0.1607	0.1556	0.1448	0.0108	0.	1.043	2.269	0.033	4.623	0.594
199		0.1557	0.1448	0.0109	0.	1.044	2.333	0.037	4.721	0.624
204	0.1866	0.1563	0.1449	0.0114	0.	1.050	2.636	0.179	5.122	0.767
206	0.1549	0.1566	0.1449	0.0117	0.	1.052	2.747	0.115	5.226	0.825
210	0.1479	0.1571	0.1449	0.0122	0.	1.053	2.945	0.077	5.382	0.938
212		0.1574	0.1449	0.0125	0.	1.053	3.030	0.065	5.413	0.894
213	0.1600	0.1575	0.1449	0.0126	0.	1.053	3.070	0.054	5.417	1.021
217		0.1582	0.1449	0.0132	0.	1.051	3.199	0.043	5.368	1.125
218		0.1583	0.1449	0.0134	0.	1.051	3.225	0.217	5.338	1.150
220		0.1587	0.1449	0.0138	0.	1.049	3.266	0.059	5.260	1.198
221	0.1493	0.1589	0.1449	0.0139	0.	1.048	3.281	0.111	5.211	1.221
224		0.1594	0.1449	0.0145	0.	1.044	3.306	0.108	5.029	1.287
225	0.1514	0.1596	0.1449	0.0147	0.	1.042	3.308	0.082	4.957	1.307
231	0.1592	0.1606	0.1448	0.0159	0.	1.030	3.229	0.298	4.421	1.409
240	0.1607	0.1614	0.1440	0.0174	0.	1.005	2.800	0.063	3.402	1.413
247	0.1412	0.1586	0.1418	0.0168	0.	0.978	2.165	0.157	2.602	1.400
254	0.1600	0.1489	0.1372	0.0116	0.	0.946	1.226	0.103	1.995	1.385
268		0.1441	0.1361	0.0080	0.	0.956	0.800	0.162	1.900	1.370

A_{leaf}=0.1450 B_{stalk}=0.0310 C_{soil}=0.1442 D=5.0000 E=1.4671

CORRELATION COEFFICIENT=0.9522

MANHATTAN AGRICULTURAL EXPERIMENT

1980 SORGHUM S-31
35.6 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
158	0.0226	0.0380	0.0118	0.	0.0262	0.102	0.005	0.268	0.070	0.009
161	0.0513	0.0351	0.0150	0.	0.0201	0.198	0.079	0.212	0.090	0.010
165		0.0332	0.0197	0.	0.0135	0.356	0.218	0.151	0.120	0.017
168	0.0646	0.0647	0.0545	0.	0.0101	0.486	0.349	0.160	0.382	0.027
170	0.1062	0.0845	0.0819	0.	0.0026	0.574	0.448	0.057	0.659	0.037
171		0.0949	0.0929	0.	0.0020	0.617	0.500	0.054	0.801	0.044
176	0.1432	0.1311	0.1274	0.	0.0037	0.821	0.788	0.257	1.485	0.088
178	0.1337	0.1364	0.1344	0.	0.0020	0.890	0.913	0.191	1.725	0.120
182		0.1476	0.1472	0.	0.0003	0.996	1.175	0.074	2.456	0.194
189		0.1544	0.1543	0.	0.0001	1.024	1.657	0.109	3.509	0.353
190	0.1416	0.1549	0.1548	0.	0.0001	1.027	1.727	0.082	3.649	0.379
192	0.1811	0.1555	0.1555	0.	0.	1.031	1.865	0.056	3.920	0.431
196	0.1528	0.1564	0.1563	0.	0.	1.039	2.137	0.041	4.409	0.539
198	0.1754	0.1566	0.1565	0.	0.	1.043	2.269	0.033	4.623	0.594
199		0.1567	0.1566	0.	0.	1.044	2.333	0.037	4.721	0.624
204	0.1959	0.1570	0.1569	0.	0.	1.050	2.636	0.179	5.122	0.767
206	0.1742	0.1571	0.1570	0.	0.	1.052	2.747	0.115	5.226	0.825
210	0.1358	0.1571	0.1571	0.0001	0.	1.053	2.945	0.077	5.382	0.938
212		0.1571	0.1571	0.0001	0.	1.053	3.030	0.065	5.413	0.894
213	0.1626	0.1571	0.1571	0.0001	0.	1.053	3.070	0.054	5.417	1.021
217		0.1571	0.1571	0.0001	0.	1.051	3.199	0.043	5.368	1.125
218		0.1571	0.1570	0.0001	0.	1.051	3.225	0.217	5.338	1.150
220		0.1571	0.1570	0.0001	0.	1.049	3.266	0.059	5.260	1.198
221	0.1570	0.1571	0.1570	0.0001	0.	1.048	3.281	0.111	5.211	1.221
224		0.1569	0.1569	0.0001	0.	1.044	3.306	0.108	5.029	1.287
225	0.1592	0.1569	0.1568	0.0001	0.	1.042	3.308	0.082	4.957	1.307
231	0.1422	0.1564	0.1563	0.0001	0.	1.030	3.229	0.298	4.421	1.409
240	0.1365	0.1540	0.1539	0.0001	0.	1.005	2.800	0.063	3.402	1.413
247	0.1089	0.1492	0.1488	0.0001	0.0003	0.978	2.165	0.157	2.602	1.400
254	0.1194	0.1411	0.1404	0.	0.0007	0.946	1.226	0.103	1.995	1.385
268		0.1399	0.1385	0.	0.0014	0.956	0.800	0.162	1.900	1.370

A_{leaf}=0.1575 B_{stalk}=0.0001 C_{soil}=0.1057 D=0.5052 E=1.1138

CORRELATION COEFFICIENT=0.8995

MANHATTAN AGRICULTURAL EXPERIMENT

1980 SORGHUM S-32
8.6 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
158	0.0507	0.0424	0.0101	0.0012	0.0311	0.154	0.113	0.228	0.060	0.005
161	0.0417	0.0475	0.0177	0.0022	0.0276	0.245	0.141	0.243	0.110	0.009
165	0.0427	0.0488	0.0295	0.0055	0.0139	0.383	0.239	0.195	0.200	0.016
168	0.0525	0.0567	0.0423	0.0091	0.0053	0.493	0.347	0.141	0.320	0.035
170	0.0741	0.0655	0.0523	0.0119	0.0013	0.567	0.436	0 063	0.440	0.051
176	0.0908	0.0959	0.0788	0.0168	0.0003	0.778	0.723	0.229	1.068	0.108
178	0.0912	0.1007	0.0834	0.0173	0.0001	0.840	0.826	0.198	1.357	0.129
182	0.0935	0.1052	0.0875	0.0178	0.	0.943	1.035	0.120	1.943	0.175
189		0.1059	0.0890	0.0169	0.	1.026	1.307	0.074	2.853	0.264
190	0.1122	0.1071	0.0890	0.0181	0.	1.046	1.418	0.080	2.960	0.277
192	0.0955	0.1071	0.0891	0.0180	0.	1.046	1.500	0.052	3.152	0.303
196	0.1122	0.1071	0.0892	0.0179	0.	1.040	1.641	0.038	3.435	0.358
198	0.1159	0.1073	0.0892	0.0181	0.	1.037	1.700	0.032	3.522	0.385
199		0.1074	0.0892	0.0182	0.	1.035	1.725	0.030	3.551	0.399
204	0.1297	0.1082	0.0892	0.0190	0.	1.027	1.819	0.129	3.551	0.466
206	0.1042	0.1087	0.0892	0.0195	0.	1.024	1.839	0.062	3.484	0.493
210	0.1297	0.1101	0.0891	0.0210	0.	1.018	1.851	0.069	3.243	0.544
212		0.1110	0.0891	0.0219	0.	1.015	1.843	0.060	3.075	0.569
213	0.1178	0.1115	0.0890	0.0225	0.	1.013	1.835	0.052	2.980	0.581
217	0.1074	0.1141	0.0887	0.0253	0.	1.007	1.781	0.039	2.542	0.627
218		0.1148	0.0886	0.0262	0.	1.005	1.763	0.149	2.422	0.638
220		0.1164	0.0881	0.0283	0.	1.002	1.720	0.097	2.172	0.659
221	0.0955	0.1173	0.0878	0.0295	0.	1.000	1.696	0.106	2.044	0.669
224		0.1198	0.0861	0.0337	0.	0.996	1.614	0.163	1.661	0.697
225	0.1096	0.1205	0.0852	0.0353	0.	0.994	1.584	0.087	1.536	0.706
231	0.1213	0.1203	0.0745	0.0458	0.	0.985	1.383	0.278	0.897	0.749
240	0.1309	0.1086	0.0692	0.0394	0.	0.971	1.079	0.087	0.744	0.782
247	0.0885	0.1042	0.0650	0.0391	0.0001	0.960	1.005	0.214	0.650	0.774
254	0.1074	0.0994	0.0614	0.0380	0.	0.949	0.935	0.079	0.580	0.734
268		0.0907	0.0565	0.0339	0.0002	0.927	0.800	0.164	0.500	0.680

A_{leaf}=0.0893 B_{stalk}=0.0725 C_{soil}=0.1677 D=5.0000 E=2.0050

CORRELATION COEFFICIENT=0.9005

MANHATTAN AGRICULTURAL EXPERIMENT

1980 SORGHUM S-32
13.0 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
158	0.0652	0.0523	0.0094	0.0013	0.0416	0.154	0.113	0.228	0.060	0.005
161	0.0490	0.0572	0.0167	0.0025	0.0380	0.245	0.141	0.243	0.110	0.009
165	0.0417	0.0549	0.0286	0.0061	0.0202	0.383	0.239	0.195	0.200	0.016
168	0.0631	0.0610	0.0422	0.0106	0.0083	0.493	0.347	0.141	0.320	0.035
170	0.0861	0.0700	0.0537	0.0142	0.0021	0.567	0.436	0.063	0.440	0.051
176	0.1009	0.1133	0.0904	0.0223	0.0007	0.778	0.723	0.229	1.068	0.108
178	0.1114	0.1229	0.0989	0.0237	0.0002	0.840	0.826	0.198	1.357	0.129
182	0.1390	0.1341	0.1085	0.0256	0.	0.943	1.035	0.120	1.943	0.175
189		0.1391	0.1139	0.0251	0.	1.026	1.307	0.074	2.853	0.264
190	0.1472	0.1411	0.1142	0.0269	0.	1.046	1.418	0.080	2.960	0.277
192	0.1419	0.1414	0.1146	0.0268	0.	1.046	1.500	0.052	3.152	0.303
196	0.1288	0.1419	0.1151	0.0268	0.	1.040	1.641	0.038	3.435	0.358
198	0.1374	0.1422	0.1152	0.0270	0.	1.037	1.700	0.032	3.522	0.385
199		0.1424	0.1152	0.0272	0.	1.035	1.725	0.030	3.551	0.399
204	0.1637	0.1437	0.1152	0.0284	0.	1.027	1.819	0.129	3.551	0.466
206	0.1483	0.1444	0.1151	0.0292	0.	1.024	1.839	0.062	3.484	0.493
210	0.1663	0.1461	0.1148	0.0313	0.	1.018	1.851	0.069	3.243	0.544
212		0.1471	0.1145	0.0327	0.	1.015	1.843	0.060	3.075	0.569
213	0.1324	0.1477	0.1143	0.0334	0.	1.013	1.835	0.052	2.980	0.581
217	0.1663	0.1501	0.1128	0.0373	0.	1.007	1.781	0.039	2.542	0.627
218		0.1507	0.1122	0.0385	0.	1.005	1.763	0.149	2.422	0.638
220		0.1518	0.1106	0.0412	0.	1.002	1.720	0.097	2.172	0.659
221	0.1259	0.1522	0.1095	0.0427	0.	1.000	1.696	0.106	2.044	0.669
224		0.1525	0.1049	0.0476	0.	0.996	1.614	0.163	1.661	0.697
225	0.1432	0.1522	0.1028	0.0494	0.	0.994	1.584	0.087	1.536	0.706
231	0.1349	0.1427	0.0833	0.0594	0.	0.985	1.383	0.278	0.897	0.749
240	0.1412	0.1253	0.0755	0.0498	0.	0.971	1.079	0.087	0.744	0.782
247	0.1262	0.1184	0.0697	0.0485	0.0001	0.960	1.005	0.214	0.650	0.774
254	0.1117	0.1115	0.0649	0.0466	0.0001	0.949	0.935	0.079	0.580	0.734
268		0.1001	0.0588	0.0409	0.0004	0.927	0.800	0.164	0.500	0.680

A_{leaf}=0.1160 B_{stalk}=0.0769 C_{soil}=0.2168 D=5.0000 E=1.4130

CORRELATION COEFFICIENT=0.9358

MANHATTAN AGRICULTURAL EXPERIMENT

1980 SORGHUM S-32
17.0 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
158	0.0400	0.0440	0.0056	0.0019	0.0365	0.154	0.113	0.228	0.060	0.005
161	0.0537	0.0478	0.0101	0.0036	0.0341	0.245	0.141	0.243	0.110	0.009
165	0.0398	0.0456	0.0175	0.0092	0.0189	0.383	0.239	0.195	0.200	0.016
168	0.0501	0.0511	0.0266	0.0163	0.0082	0.493	0.347	0.141	0.320	0.035
170	0.0813	0.0593	0.0347	0.0224	0.0022	0.567	0.436	0.063	0.440	0.051
176	0.1233	0.1049	0.0648	0.0392	0.0009	0.778	0.723	0.229	1.068	0.108
178	0.0955	0.1173	0.0737	0.0432	0.0003	0.840	0.826	0.198	1.357	0.129
182	0.1002	0.1353	0.0858	0.0495	0.	0.943	1.035	0.120	1.943	0.175
189		0.1466	0.0952	0.0514	0.	1.026	1.307	0.074	2.853	0.264
190	0.1633	0.1510	0.0959	0.0551	0.	1.046	1.418	0.080	2.960	0.277
192	0.1462	0.1523	0.0969	0.0554	0.	1.046	1.500	0.052	3.152	0.303
196	0.1531	0.1541	0.0981	0.0560	0.	1.040	1.641	0.038	3.435	0.358
198	0.1679	0.1550	0.0985	0.0565	0.	1.037	1.700	0.032	3.522	0.385
199		0.1554	0.0986	0.0569	0.	1.035	1.725	0.030	3.551	0.399
204	0.1862	0.1581	0.0985	0.0595	0.	1.027	1.819	0.129	3.551	0.466
206	0.1722	0.1593	0.0983	0.0610	0.	1.024	1.839	0.062	3.484	0.493
210	0.1500	0.1622	0.0973	0.0649	0.	1.018	1.851	0.069	3.243	0.544
212		0.1639	0.0965	0.0674	0.	1.015	1.843	0.060	3.075	0.569
213	0.1762	0.1647	0.0960	0.0687	0.	1.013	1.835	0.052	2.980	0.581
217	0.1758	0.1680	0.0928	0.0752	0.	1.007	1.781	0.039	2.542	0.627
218		0.1687	0.0917	0.0770	0.	1.005	1.763	0.149	2.422	0.638
220		0.1700	0.0889	0.0810	0.	1.002	1.720	0.097	2.172	0.659
221	0.1262	0.1704	0.0873	0.0831	0.	1.000	1.696	0.106	2.044	0.669
224		0.1705	0.0808	0.0897	0.	0.996	1.614	0.163	1.661	0.697
225	0.1503	0.1700	0.0781	0.0919	0.	0.994	1.584	0.087	1.536	0.706
231	0.1667	0.1599	0.0583	0.1016	0.	0.985	1.383	0.278	0.897	0.749
240	0.1403	0.1347	0.0515	0.0832	0.	0.971	1.079	0.087	0.744	0.782
247	0.1288	0.1266	0.0468	0.0797	0.0002	0.960	1.005	0.214	0.650	0.774
254	0.1400	0.1186	0.0430	0.0755	0.0001	0.949	0.935	0.079	0.580	0.734
268		0.1041	0.0384	0.0653	0.0005	0.927	0.800	0.164	0.500	0.680

A_{leaf}=0.1022 B_{stalk}=0.1105 C_{soil}=0.1848 D=5.0000 E=0.9420

CORRELATION COEFFICIENT=0.9233

MANHATTAN AGRICULTURAL EXPERIMENT

1980 SORGHUM S-32
35.6 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
158	0.0283	0.0355	0.0165	0.0003	0.0188	0.154	0.113	0.228	0.060	0.005
161	0.0575	0.0464	0.0291	0.0005	0.0168	0.245	0.141	0.243	0.110	0.009
165	0.0494	0.0590	0.0493	0.0012	0.0085	0.383	0.239	0.195	0.200	0.016
168	0.0883	0.0772	0.0719	0.0021	0.0033	0.493	0.347	0.141	0.320	0.035
170	0.0776	0.0940	0.0904	0.0028	0.0008	0.567	0.436	0.063	0.440	0.051
176	0.1629	0.1493	0.1449	0.0042	0.0002	0.778	0.723	0.229	1.068	0.108
178		0.1607	0.1562	0.0044	0.	0.840	0.826	0.198	1.357	0.129
182		0.1723	0.1677	0.0046	0.	0.943	1.035	0.120	1.943	0.175
189		0.1776	0.1731	0.0045	0.	1.026	1.307	0.074	2.853	0.264
190	0.1671	0.1781	0.1734	0.0048	0.	1.046	1.418	0.080	2.960	0.277
192	0.1845	0.1785	0.1737	0.0048	0.	1.046	1.500	0.052	3.152	0.303
196	0.1618	0.1788	0.1741	0.0048	0.	1.040	1.641	0.038	3.435	0.358
198	0.2085	0.1789	0.1741	0.0048	0.	1.037	1.700	0.032	3.522	0.385
199		0.1790	0.1742	0.0048	0.	1.035	1.725	0.030	3.551	0.399
204	0.1807	0.1792	0.1742	0.0050	0.	1.027	1.819	0.129	3.551	0.466
206	0.1866	0.1793	0.1741	0.0052	0.	1.024	1.839	0.062	3.484	0.493
210	0.1633	0.1794	0.1738	0.0056	0.	1.018	1.851	0.069	3.243	0.544
212		0.1794	0.1736	0.0058	0.	1.015	1.843	0.060	3.075	0.569
213	0.1722	0.1794	0.1734	0.0060	0.	1.013	1.835	0.052	2.980	0.581
217	0.1841	0.1787	0.1721	0.0067	0.	1.007	1.781	0.039	2.542	0.627
218		0.1784	0.1715	0.0069	0.	1.005	1.763	0.149	2.422	0.638
220		0.1773	0.1699	0.0074	0.	1.002	1.720	0.097	2.172	0.659
221	0.1560	0.1765	0.1687	0.0077	0.	1.000	1.696	0.106	2.044	0.669
224		0.1722	0.1635	0.0087	0.	0.996	1.614	0.163	1.661	0.697
225	0.1849	0.1700	0.1609	0.0091	0.	0.994	1.584	0.087	1.536	0.706
231	0.1542	0.1464	0.1351	0.0113	0.	0.985	1.383	0.278	0.897	0.749
240	0.1641	0.1333	0.1237	0.0096	0.	0.971	1.079	0.087	0.744	0.782
247	0.0891	0.1246	0.1151	0.0094	0.	0.960	1.005	0.214	0.650	0.774
254	0.1127	0.1169	0.1078	0.0091	0.	0.949	0.935	0.079	0.580	0.734
268		0.1065	0.0984	0.0080	0.0001	0.927	0.800	0.164	0.500	0.680

A_{leaf}=0.1747 B_{stalk}=0.0159 C_{soil}=0.1000 D=5.4710 E=1.6560

CORRELATION COEFFICIENT=0.9501

MANHATTAN AGRICULTURAL EXPERIMENT

1980 SORGHUM S-33
8.6 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
158	0.0643	0.0436	0.0139	0.0007	0.0290	0.154	0.080	0.243	0.080	0.001
161	0.0363	0.0467	0.0214	0.0005	0.0248	0.241	0.037	0.225	0.129	0.003
163		0.0493	0.0315	0.0014	0.0164	0.305	0.088	0.188	0.203	0.005
165	0.0316	0.0541	0.0419	0.0027	0.0096	0.373	0.150	0.151	0.292	0.009
168	0.0380	0.0675	0.0567	0.0051	0.0056	0.480	0.259	0.169	0.453	0.024
170	0.0918	0.0740	0.0655	0.0070	0.0015	0.552	0.341	0.079	0.579	0.036
171	0.0973	0.0783	0.0694	0.0080	0.0009	0.587	0.383	0.065	0.647	0.042
176	0.0912	0.0972	0.0843	0.0124	0.0005	0.760	0.609	0.258	1.039	0.081
178	0.1104	0.1021	0.0882	0.0138	0.0001	0.822	0.703	0.142	1.220	0.099
182	0.1000	0.1089	0.0924	0.0165	0.	0.930	0.889	0.085	1.526	0.138
189	0.1186	0.1125	0.0968	0.0157	0.	1.037	1.189	0.102	2.512	0.215
190	0.1318	0.1130	0.0968	0.0162	0.	1.048	1.228	0.094	2.547	0.227
192	0.1183	0.1136	0.0969	0.0168	0.	1.040	1.301	0.063	2.583	0.251
196	0.1180	0.1151	0.0969	0.0182	0.	1.039	1.429	0.034	2.614	0.300
198	0.1268	0.1158	0.0969	0.0189	0.	1.038	1.482	0.037	2.612	0.325
199		0.1161	0.0969	0.0192	0.	1.038	1.506	0.037	2.607	0.337
204	0.1236	0.1176	0.0968	0.0208	0.	1.036	1.597	0.156	2.543	0.399
206	0.0951	0.1183	0.0968	0.0215	0.	1.035	1.627	0.092	2.502	0.424
210	0.0933	0.1191	0.0966	0.0226	0.	1.032	1.642	0.089	2.396	0.472
212	0.1146	0.1196	0.0965	0.0232	0.	1.030	1.649	0.078	2.333	0.496
213	0.1096	0.1197	0.0964	0.0233	0.	1.029	1.638	0.068	2.299	0.507
217	0.1035	0.1203	0.0960	0.0243	0.	1.026	1.606	0.044	2.152	0.551
218		0.1204	0.0959	0.0245	0.	1.025	1.594	0.188	2.113	0.561
220		0.1205	0.0956	0.0249	0.	1.022	1.565	0.090	2.032	0.582
221	0.1138	0.1205	0.0954	0.0250	0.	1.021	1.547	0.084	1.990	0.591
224	0.1265	0.1203	0.0948	0.0255	0.	1.018	1.488	0.126	1.863	0.619
225	0.1256	0.1202	0.0946	0.0256	0.	1.017	1.465	0.113	1.819	0.627
231	0.1493	0.1187	0.0927	0.0260	0.	1.008	1.311	0.288	1.560	0.670
240	0.1333	0.1133	0.0879	0.0254	0.	0.994	1.061	0.067	1.204	0.706
247	0.0995	0.1078	0.0831	0.0247	0.0001	0.981	0.910	0.208	0.993	0.704
254	0.0962	0.1046	0.0795	0.0251	0.0001	0.966	0.868	0.131	0.877	0.670
268		0.1003	0.0766	0.0236	0.0001	0.932	0.800	0.126	0.800	0.650

A_{leaf}=0.0976 B_{stalk}=0.0619 C_{soil}=0.1478 D=5.0000 E=1.9230

CORRELATION COEFFICIENT=0.8442

MANHATTAN AGRICULTURAL EXPERIMENT

1980 SORGHUM S-33
13.0 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
158	0.0661	0.0459	0.0146	0.0005	0.0307	0.154	0.080	0.243	0.080	0.001
161	0.0407	0.0500	0.0227	0.0004	0.0269	0.241	0.037	0.225	0.129	0.003
163		0.0535	0.0340	0.0010	0.0184	0.305	0.088	0.188	0.203	0.005
165	0.0380	0.0593	0.0460	0.0021	0.0112	0.373	0.150	0.151	0.292	0.009
168	0.0525	0.0753	0.0641	0.0041	0.0071	0.480	0.259	0.169	0.453	0.024
170	0.0912	0.0833	0.0756	0.0057	0.0020	0.552	0.341	0.079	0.579	0.036
171	0.0957	0.0887	0.0809	0.0065	0.0012	0.587	0.383	0.065	0.647	0.042
176	0.1159	0.1149	0.1033	0.0107	0.0008	0.760	0.609	0.258	1.039	0.081
178	0.1384	0.1223	0.1100	0.0121	0.0002	0.822	0.703	0.142	1.220	0.099
182	0.1500	0.1329	0.1180	0.0148	0.	0.930	0.889	0.085	1.526	0.138
189	0.1469	0.1434	0.1288	0.0147	0.	1.037	1.189	0.102	2.512	0.215
190	0.1483	0.1440	0.1289	0.0151	0.	1.048	1.228	0.094	2.547	0.227
192	0.1578	0.1448	0.1291	0.0157	0.	1.040	1.301	0.063	2.583	0.251
196	0.1626	0.1463	0.1292	0.0170	0.	1.039	1.429	0.034	2.614	0.300
198	0.1652	0.1469	0.1292	0.0177	0.	1.038	1.482	0.037	2.612	0.325
199		0.1472	0.1292	0.0180	0.	1.038	1.506	0.037	2.607	0.337
204	0.1563	0.1484	0.1289	0.0195	0.	1.036	1.597	0.156	2.543	0.399
206	0.1465	0.1488	0.1287	0.0201	0.	1.035	1.627	0.092	2.502	0.424
210	0.1567	0.1492	0.1281	0.0210	0.	1.032	1.642	0.089	2.396	0.472
212	0.1309	0.1494	0.1278	0.0216	0.	1.030	1.649	0.078	2.333	0.496
213	0.1377	0.1493	0.1275	0.0217	0.	1.029	1.638	0.068	2.299	0.507
217	0.1349	0.1489	0.1265	0.0225	0.	1.026	1.606	0.044	2.152	0.551
218		0.1488	0.1261	0.0226	0.	1.025	1.594	0.188	2.113	0.561
220		0.1483	0.1254	0.0229	0.	1.022	1.565	0.090	2.032	0.582
221	0.1175	0.1480	0.1249	0.0230	0.	1.021	1.547	0.084	1.990	0.591
224	0.1396	0.1468	0.1235	0.0233	0.	1.018	1.488	0.126	1.863	0.619
225	0.1227	0.1463	0.1229	0.0234	0.	1.017	1.465	0.113	1.819	0.627
231	0.1514	0.1421	0.1187	0.0234	0.	1.008	1.311	0.288	1.560	0.670
240	0.1276	0.1318	0.1095	0.0223	0.	0.994	1.061	0.067	1.204	0.706
247	0.1368	0.1226	0.1013	0.0211	0.0001	0.981	0.910	0.208	0.993	0.704
254	0.1122	0.1169	0.0956	0.0212	0.0001	0.966	0.868	0.131	0.877	0.670
268		0.1111	0.0912	0.0197	0.0001	0.932	0.800	0.126	0.800	0.650

A_{leaf}=0.1321 B_{stalk}=0.0450 C_{soil}=0.1510 D=5.0000 E=1.4680

CORRELATION COEFFICIENT=0.9178

MANHATTAN AGRICULTURAL EXPERIMENT

1980 SORGHUM S-33
17.0 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
158	0.0579	0.0475	0.0120	0.0011	0.0344	0.154	0.080	0.243	0.080	0.001
161	0.0490	0.0499	0.0187	0.0007	0.0305	0.241	0.037	0.225	0.129	0.003
163		0.0516	0.0282	0.0021	0.0212	0.305	0.088	0.188	0.203	0.005
165	0.0398	0.0559	0.0385	0.0042	0.0131	0.373	0.150	0.151	0.292	0.009
168	0.0562	0.0716	0.0545	0.0086	0.0086	0.480	0.259	0.169	0.453	0.024
170	0.0679	0.0794	0.0649	0.0121	0.0025	0.552	0.341	0.079	0.579	0.036
171	0.0951	0.0853	0.0698	0.0139	0.0016	0.587	0.383	0.065	0.647	0.042
176	0.1306	0.1161	0.0916	0.0234	0.0011	0.760	0.609	0.258	1.039	0.081
178	0.1570	0.1255	0.0985	0.0267	0.0003	0.822	0.703	0.142	1.220	0.099
182	0.1239	0.1404	0.1072	0.0332	0.	0.930	0.889	0.085	1.526	0.138
189	0.1445	0.1541	0.1203	0.0338	0.	1.037	1.189	0.102	2.512	0.215
190	0.1435	0.1554	0.1205	0.0349	0.	1.048	1.228	0.094	2.547	0.227
192	0.1426	0.1570	0.1208	0.0362	0.	1.040	1.301	0.063	2.583	0.251
196	0.1698	0.1603	0.1209	0.0393	0.	1.039	1.429	0.034	2.614	0.300
198	0.1832	0.1617	0.1209	0.0408	0.	1.038	1.482	0.037	2.612	0.325
199		0.1624	0.1209	0.0415	0.	1.038	1.506	0.037	2.607	0.337
204	0.1766	0.1654	0.1205	0.0449	0.	1.036	1.597	0.156	2.543	0.399
206	0.1698	0.1665	0.1202	0.0463	0.	1.035	1.627	0.092	2.502	0.424
210	0.1690	0.1678	0.1195	0.0484	0.	1.032	1.642	0.089	2.396	0.472
212	0.1726	0.1685	0.1189	0.0496	0.	1.030	1.649	0.078	2.333	0.496
213	0.1722	0.1685	0.1187	0.0498	0.	1.029	1.638	0.068	2.299	0.507
217	0.1618	0.1686	0.1172	0.0514	0.	1.026	1.606	0.044	2.152	0.551
218		0.1685	0.1168	0.0517	0.	1.025	1.594	0.188	2.113	0.561
220		0.1681	0.1159	0.0522	0.	1.022	1.565	0.090	2.032	0.582
221	0.1603	0.1678	0.1153	0.0524	0.	1.021	1.547	0.084	1.990	0.591
224	0.1641	0.1664	0.1135	0.0529	0.	1.018	1.488	0.126	1.863	0.619
225	0.1545	0.1658	0.1129	0.0529	0.	1.017	1.465	0.113	1.819	0.627
231	0.1618	0.1603	0.1079	0.0524	0.	1.008	1.311	0.288	1.560	0.670
240	0.1343	0.1470	0.0979	0.0491	0.	0.994	1.061	0.067	1.204	0.706
247	0.1208	0.1357	0.0895	0.0461	0.0001	0.981	0.910	0.208	0.993	0.704
254	0.1552	0.1299	0.0839	0.0459	0.0001	0.966	0.868	0.131	0.877	0.670
268		0.1223	0.0796	0.0425	0.0002	0.932	0.800	0.126	0.800	0.650

A_{leaf}=0.1257 B_{stalk}=0.0903 C_{soil}=0.1663 D=5.0000 E=1.2550

CORRELATION COEFFICIENT=0.9514

MANHATTAN AGRICULTURAL EXPERIMENT

1980 SORGHUM S-33
35.6 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
158	0.0316	0.0467	0.0132	0.	0.0335	0.154	0.080	0.243	0.080	0.001
161	0.0549	0.0507	0.0208	0.	0.0299	0.241	0.037	0.225	0.129	0.003
163		0.0551	0.0318	0.	0.0233	0.305	0.088	0.188	0.203	0.005
165	0.0527	0.0613	0.0443	0.	0.0171	0.373	0.150	0.151	0.292	0.009
168	0.0920	0.0808	0.0647	0.	0.0161	0.480	0.259	0.169	0.453	0.024
170	0.1002	0.0854	0.0789	0.	0.0065	0.552	0.341	0.079	0.579	0.036
171	0.1005	0.0910	0.0860	0.	0.0050	0.587	0.383	0.065	0.647	0.042
176	0.1556	0.1329	0.1205	0.	0.0124	0.760	0.609	0.258	1.039	0.081
178	0.1500	0.1386	0.1331	0.	0.0055	0.822	0.703	0.142	1.220	0.099
182		0.1530	0.1508	0.	0.0022	0.930	0.889	0.085	1.526	0.138
189	0.2061	0.1868	0.1858	0.0001	0.0009	1.037	1.189	0.102	2.512	0.215
190	0.2296	0.1874	0.1866	0.0001	0.0008	1.048	1.228	0.094	2.547	0.227
192	0.1959	0.1879	0.1874	0.0001	0.0005	1.040	1.301	0.063	2.583	0.251
196	0.2158	0.1884	0.1881	0.0001	0.0002	1.039	1.429	0.034	2.614	0.300
198	0.2094	0.1884	0.1880	0.0001	0.0003	1.038	1.482	0.037	2.612	0.325
199		0.1882	0.1879	0.0001	0.0003	1.038	1.506	0.037	2.607	0.337
204	0.1766	0.1876	0.1865	0.0001	0.0011	1.036	1.597	0.156	2.543	0.399
206	0.1766	0.1862	0.1855	0.0001	0.0006	1.035	1.627	0.092	2.502	0.424
210	0.1560	0.1836	0.1829	0.0001	0.0007	1.032	1.642	0.089	2.396	0.472
212	0.1489	0.1819	0.1812	0.0001	0.0006	1.030	1.649	0.078	2.333	0.496
213	0.1927	0.1809	0.1803	0.0001	0.0005	1.029	1.638	0.068	2.299	0.507
217	0.1766	0.1765	0.1760	0.0001	0.0004	1.026	1.606	0.044	2.152	0.551
218		0.1766	0.1748	0.0001	0.0018	1.025	1.594	0.188	2.113	0.561
220		0.1731	0.1721	0.0001	0.0009	1.022	1.565	0.090	2.032	0.582
221	0.1309	0.1716	0.1706	0.0001	0.0009	1.021	1.547	0.084	1.990	0.591
224	0.1227	0.1675	0.1659	0.0001	0.0016	1.018	1.488	0.126	1.863	0.619
225	0.1535	0.1657	0.1641	0.0001	0.0015	1.017	1.465	0.113	1.819	0.627
231	0.1629	0.1578	0.1525	0.0001	0.0052	1.008	1.311	0.288	1.560	0.670
240	0.1406	0.1340	0.1320	0.0001	0.0019	0.994	1.061	0.067	1.204	0.706
247	0.1099	0.1249	0.1170	0.0001	0.0078	0.981	0.910	0.208	0.993	0.704
254	0.1211	0.1132	0.1075	0.0001	0.0056	0.966	0.868	0.131	0.877	0.670
268		0.1069	0.1007	0.0001	0.0061	0.932	0.800	0.126	0.800	0.650

A_{leaf}=0.2156 B_{stalk}=0.0001 C_{soil}=0.1479 D=0.6855 E=0.7871

CORRELATION COEFFICIENT=0.9133

MANHATTAN AGRICULTURAL EXPERIMENT

1980 SORGHUM S-31
8.6 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
158	0.0632	0.0582	0.0082	0.	0.0500	0.102	0.005	0.268	0.070	0.009
161	0.0372	0.0468	0.0104	0.0006	0.0357	0.198	0.079	0.212	0.090	0.010
165		0.0347	0.0137	0.0030	0.0180	0.356	0.218	0.151	0.120	0.017
168	0.0617	0.0515	0.0372	0.0057	0.0086	0.486	0.349	0.160	0.382	0.027
170	0.0692	0.0638	0.0550	0.0074	0.0014	0.574	0.448	0.057	0.659	0.037
171		0.0711	0.0620	0.0082	0.0009	0.617	0.500	0.054	0.801	0.044
176	0.0851	0.0954	0.0828	0.0123	0.0003	0.821	0.788	0.257	1.485	0.088
178	0.0955	0.1008	0.0867	0.0140	0.0001	0.890	0.913	0.191	1.725	0.120
182	0.1233	0.1088	0.0935	0.0153	0.	0.996	1.175	0.074	2.456	0.194
189		0.1129	0.0969	0.0160	0.	1.024	1.657	0.109	3.509	0.353
190	0.1156	0.1132	0.0971	0.0162	0.	1.027	1.727	0.082	3.649	0.379
192	0.1256	0.1137	0.0973	0.0164	0.	1.031	1.865	0.056	3.920	0.431
196	0.1096	0.1145	0.0977	0.0169	0.	1.039	2.137	0.041	4.409	0.539
198	0.1189	0.1149	0.0978	0.0171	0.	1.043	2.269	0.033	4.623	0.594
199		0.1151	0.0978	0.0173	0.	1.044	2.333	0.037	4.721	0.624
204	0.1211	0.1160	0.0979	0.0181	0.	1.050	2.636	0.179	5.122	0.767
206	0.1207	0.1165	0.0979	0.0185	0.	1.052	2.747	0.115	5.226	0.825
210	0.1262	0.1173	0.0980	0.0193	0.	1.053	2.945	0.077	5.382	0.938
212		0.1178	0.0980	0.0198	0.	1.053	3.030	0.065	5.413	0.894
213	0.1297	0.1180	0.0980	0.0200	0.	1.053	3.070	0.054	5.417	1.021
217		0.1190	0.0980	0.0210	0.	1.051	3.199	0.043	5.368	1.125
218		0.1193	0.0980	0.0213	0.	1.051	3.225	0.217	5.338	1.150
220		0.1198	0.0979	0.0219	0.	1.049	3.266	0.059	5.260	1.198
221	0.1091	0.1201	0.0979	0.0221	0.	1.048	3.281	0.111	5.211	1.221
224		0.1209	0.0979	0.0230	0.	1.044	3.306	0.108	5.029	1.287
225	0.1151	0.1212	0.0979	0.0233	0.	1.042	3.308	0.082	4.957	1.307
231	0.1216	0.1229	0.0977	0.0252	0.	1.030	3.229	0.298	4.421	1.409
240	0.1202	0.1241	0.0967	0.0274	0.	1.005	2.800	0.063	3.402	1.413
247	0.1161	0.1206	0.0943	0.0263	0.	0.978	2.165	0.157	2.602	1.400
254	0.0933	0.1079	0.0900	0.0179	0.	0.946	1.226	0.103	1.995	1.385
268		0.1013	0.0890	0.0123	0.0001	0.956	0.800	0.162	1.900	1.370

A_{leaf}=0.0981 B_{stalk}=0.0420 C_{soil}=0.2040 D=5.0000 E=1.2500

CORRELATION COEFFICIENT=0.9437

MANHATTAN AGRICULTURAL EXPERIMENT

1980 SORGHUM S-31
13.0 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
158	0.0425	0.0473	0.0096	0.	0.0377	0.102	0.005	0.268	0.070	0.009
161	0.0417	0.0395	0.0122	0.0003	0.0270	0.198	0.079	0.212	0.090	0.010
165		0.0312	0.0159	0.0016	0.0136	0.356	0.218	0.151	0.120	0.017
168	0.0692	0.0532	0.0436	0.0030	0.0066	0.486	0.349	0.160	0.382	0.027
170	0.0895	0.0699	0.0649	0.0039	0.0011	0.574	0.448	0.057	0.659	0.037
171		0.0783	0.0733	0.0044	0.0007	0.617	0.500	0.054	0.801	0.044
176	0.0946	0.1055	0.0987	0.0066	0.0003	0.821	0.788	0.257	1.485	0.088
178	0.0993	0.1112	0.1036	0.0075	0.0001	0.890	0.913	0.191	1.725	0.120
182	0.1146	0.1206	0.1123	0.0083	0.	0.996	1.175	0.074	2.456	0.194
189		0.1255	0.1168	0.0087	0.	1.024	1.657	0.109	3.509	0.353
190	0.1412	0.1258	0.1170	0.0088	0.	1.027	1.727	0.082	3.649	0.379
192	0.1318	0.1264	0.1175	0.0089	0.	1.031	1.865	0.056	3.920	0.431
196	0.1247	0.1271	0.1179	0.0092	0.	1.039	2.137	0.041	4.409	0.539
198	0.1315	0.1274	0.1181	0.0093	0.	1.043	2.269	0.033	4.623	0.594
199		0.1275	0.1181	0.0094	0.	1.044	2.333	0.037	4.721	0.624
204	0.1445	0.1281	0.1183	0.0099	0.	1.050	2.636	0.179	5.122	0.767
206	0.1309	0.1284	0.1183	0.0101	0.	1.052	2.747	0.115	5.226	0.825
210	0.1271	0.1289	0.1183	0.0105	0.	1.053	2.945	0.077	5.382	0.938
212		0.1291	0.1183	0.0108	0.	1.053	3.030	0.065	5.413	0.894
213	0.1377	0.1292	0.1183	0.0109	0.	1.053	3.070	0.054	5.417	1.021
217		0.1298	0.1183	0.0114	0.	1.051	3.199	0.043	5.368	1.125
218		0.1299	0.1183	0.0116	0.	1.051	3.225	0.217	5.338	.150
220		0.1302	0.1183	0.0119	0.	1.049	3.266	0.059	5.260	1.198
221	0.1262	0.1303	0.1183	0.0120	0.	1.048	3.281	0.111	5.211	1.221
224		0.1308	0.1182	0.0125	0.	1.044	3.306	0.108	5.029	1.287
225	0.1175	0.1309	0.1182	0.0127	0.	1.042	3.308	0.082	4.957	1.307
231	0.1374	0.1316	0.1179	0.0137	0.	1.030	3.229	0.298	4.421	1.409
240	0.1291	0.1314	0.1165	0.0149	0.	1.005	2.800	0.063	3.402	1.413
247	0.1222	0.1276	0.1133	0.0142	0.	0.978	2.165	0.157	2.602	1.400
254	0.0955	0.1174	0.1078	0.0097	0.	0.946	1.226	0.103	1.995	1.385
268		0.1131	0.1065	0.0066	0.0001	0.956	0.800	0.162	1.900	1.370

A_{leaf}=0.1185 B_{stalk}=0.0220 C_{soil}=0.1536 D=5.0000 E=1.2020

CORRELATION COEFFICIENT=0.9361

MANHATTAN AGRICULTURAL EXPERIMENT

1980 SORGHUM S-31
17.0 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
158	0.0470	0.0530	0.0126	0.	0.0404	0.102	0.005	0.268	0.070	0.009
161	0.0562	0.0451	0.0159	0.0004	0.0288	0.198	0.079	0.212	0.090	0.010
165		0.0371	0.0208	0.0018	0.0145	0.356	0.218	0.151	0.120	0.017
168	0.0537	0.0656	0.0557	0.0033	0.0067	0.486	0.349	0.160	0.382	0.027
170	0.0895	0.0862	0.0810	0.0042	0.0011	0.574	0.448	0.057	0.659	0.037
171		0.0958	0.0906	0.0046	0.0006	0.617	0.500	0.054	0.801	0.044
176	0.1153	0.1245	0.1175	0.0068	0.0002	0.821	0.788	0.257	1.485	0.088
178	0.1412	0.1300	0.1223	0.0076	0.	0.890	0.913	0.191	1.725	0.120
182	0.1429	0.1381	0.1299	0.0082	0.	0.996	1.175	0.074	2.456	0.194
189		0.1418	0.1332	0.0086	0.	1.024	1.657	0.109	3.509	0.353
190	0.1452	0.1420	0.1334	0.0086	0.	1.027	1.727	0.082	3.649	0.379
192	0.1585	0.1424	0.1336	0.0087	0.	1.031	1.865	0.056	3.920	0.431
196	0.1542	0.1429	0.1339	0.0090	0.	1.039	2.137	0.041	4.409	0.539
198	0.1603	0.1431	0.1340	0.0091	0.	1.043	2.269	0.033	4.623	0.594
199		0.1432	0.1340	0.0092	0.	1.044	2.333	0.037	4.721	0.624
204	0.1556	0.1437	0.1341	0.0096	0.	1.050	2.636	0.179	5.122	0.767
206	0.1396	0.1439	0.1341	0.0098	0.	1.052	2.747	0.115	5.226	0.825
210	0.1503	0.1444	0.1341	0.0103	0.	1.053	2.945	0.077	5.382	0.938
212		0.1446	0.1341	0.0105	0.	1.053	3.030	0.065	5.413	0.894
213	0.1626	0.1448	0.1341	0.0106	0.	1.053	3.070	0.054	5.417	1.021
217		0.1453	0.1341	0.0112	0.	1.051	3.199	0.043	5.368	1.125
218		0.1454	0.1341	0.0113	0.	1.051	3.225	0.217	5.338	1.150
220		0.1457	0.1341	0.0116	0.	1.049	3.266	0.059	5.260	1.198
221	0.1189	0.1459	0.1341	0.0117	0.	1.048	3.281	0.111	5.211	1.221
224		0.1463	0.1341	0.0122	0.	1.044	3.306	0.108	5.029	1.287
225	0.1211	0.1464	0.1341	0.0124	0.	1.042	3.308	0.082	4.957	1.307
231	0.1384	0.1473	0.1339	0.0134	0.	1.030	3.229	0.298	4.421	1.409
240	0.1426	0.1477	0.1331	0.0146	0.	1.005	2.800	0.063	3.402	1.413
247	0.1219	0.1448	0.1307	0.0141	0.	0.978	2.165	0.157	2.602	1.400
254	0.1409	0.1358	0.1260	0.0097	0.	0.946	1.226	0.103	1.995	1.385
268		0.1316	0.1249	0.0067	0.	0.956	0.800	0.162	1.900	1.370

A_{leaf}=0.1342 B_{stalk}=0.0250 C_{soil}=0.1669 D=5.0000 E=1.4033

CORRELATION COEFFICIENT=0.9226

MANHATTAN AGRICULTURAL EXPERIMENT

1980 SORGHUM S-31
35.6 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
158	0.0283	0.0439	0.0116	0.	0.0323	0.102	0.005	0.268	0.070	0.009
161	0.0575	0.0397	0.0148	0.	0.0249	0.198	0.079	0.212	0.090	0.010
165		0.0363	0.0194	0.	0.0168	0.356	0.218	0.151	0.120	0.017
168	0.0659	0.0671	0.0541	0.	0.0130	0.486	0.349	0.160	0.382	0.027
170	0.0977	0.0851	0.0817	0.	0.0034	0.574	0.448	0.057	0.659	0.037
171		0.0956	0.0929	0.	0.0027	0.617	0.500	0.054	0.801	0.044
176	0.1416	0.1342	0.1287	0.	0.0054	0.821	0.788	0.257	1.485	0.088
178	0.1493	0.1392	0.1362	0.	0.0029	0.890	0.913	0.191	1.725	0.120
182		0.1507	0.1502	0.	0.0005	0.996	1.175	0.074	2.456	0.194
189		0.1584	0.1582	0.	0.0002	1.024	1.657	0.109	3.509	0.353
190		0.1589	0.1588	0.	0.0001	1.027	1.727	0.082	3.649	0.379
192	0.1932	0.1597	0.1596	0.	0.0001	1.031	1.865	0.056	3.920	0.431
196	0.1702	0.1607	0.1606	0.	0.	1.039	2.137	0.041	4.409	0.539
198	0.1803	0.1610	0.1609	0.	0.	1.043	2.269	0.033	4.623	0.594
199		0.1611	0.1610	0.	0.	1.044	2.333	0.037	4.721	0.624
204	0.1991	0.1615	0.1614	0.0001	0.	1.050	2.636	0.179	5.122	0.767
206	0.1622	0.1615	0.1615	0.0001	0.	1.052	2.747	0.115	5.226	0.825
210	0.1297	0.1616	0.1616	0.0001	0.	1.053	2.945	0.077	5.382	0.938
212		0.1616	0.1616	0.0001	0.	1.053	3.030	0.065	5.413	0.894
213	0.1406	0.1616	0.1616	0.0001	0.	1.053	3.070	0.054	5.417	1.021
217		0.1616	0.1616	0.0001	0.	1.051	3.199	0.043	5.368	1.125
218		0.1616	0.1615	0.0001	0.	1.051	3.225	0.217	5.338	1.150
220		0.1616	0.1615	0.0001	0.	1.049	3.266	0.059	5.260	1.198
221	0.1714	0.1615	0.1615	0.0001	0.	1.048	3.281	0.111	5.211	1.221
224		0.1614	0.1613	0.0001	0.	1.044	3.306	0.108	5.029	1.287
225	0.1641	0.1613	0.1613	0.0001	0.	1.042	3.308	0.082	4.957	1.307
231	0.1500	0.1608	0.1606	0.0001	0.0001	1.030	3.229	0.298	4.421	1.409
240	0.1349	0.1579	0.1578	0.0001	0.0001	1.005	2.800	0.063	3.402	1.413
247	0.1183	0.1526	0.1519	0.0001	0.0006	0.978	2.165	0.157	2.602	1.400
254	0.1262	0.1438	0.1427	0.	0.0011	0.946	1.226	0.103	1.995	1.385
268		0.1428	0.1406	0.	0.0021	0.956	0.800	0.162	1.900	1.370

A_{leaf}=0.1621 B_{stalk}=0.0001 C_{soil}=0.1299 D=0.3596 E=1.0640

CORRELATION COEFFICIENT=0.8954

MANHATTAN AGRICULTURAL EXPERIMENT

1980 SORGHUM S-32
8.6 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
158	0.0531	0.0448	0.0086	0.0013	0.0348	0.154	0.113	0.228	0.060	0.005
161	0.0436	0.0490	0.0152	0.0025	0.0313	0.245	0.141	0.243	0.110	0.009
165	0.0398	0.0480	0.0256	0.0062	0.0161	0.383	0.239	0.195	0.200	0.016
168	0.0562	0.0542	0.0372	0.0106	0.0064	0.493	0.347	0.141	0.320	0.035
170	0.0646	0.0622	0.0467	0.0140	0.0016	0.567	0.436	0.063	0.440	0.051
176	0.0871	0.0948	0.0737	0.0207	0.0004	0.778	0.723	0.229	1.068	0.108
178	0.0875	0.1008	0.0791	0.0215	0.0001	0.840	0.826	0.198	1.357	0.129
182	0.1026	0.1070	0.0844	0.0226	0.	0.943	1.035	0.120	1.943	0.175
189		0.1086	0.0868	0.0217	0.	1.026	1.307	0.074	2.853	0.264
190	0.1239	0.1101	0.0869	0.0232	0.	1.046	1.418	0.080	2.960	0.277
192	0.1071	0.1102	0.0871	0.0231	0.	1.046	1.500	0.052	3.152	0.303
196	0.1071	0.1103	0.0872	0.0231	0.	1.040	1.641	0.038	3.435	0.358
198	0.1114	0.1105	0.0873	0.0232	0.	1.037	1.700	0.032	3.522	0.385
199		0.1106	0.0873	0.0234	0.	1.035	1.725	0.030	3.551	0.399
204	0.1276	0.1117	0.0873	0.0245	0.	1.027	1.819	0.129	3.551	0.466
206	0.1143	0.1124	0.0872	0.0251	0.	1.024	1.839	0.062	3.484	0.493
210	0.1233	0.1141	0.0871	0.0270	0.	1.018	1.851	0.069	3.243	0.544
212		0.1152	0.0870	0.0282	0.	1.015	1.843	0.060	3.075	0.569
213	0.1368	0.1158	0.0869	0.0289	0.	1.013	1.835	0.052	2.980	0.581
217	0.1175	0.1188	0.0864	0.0324	0.	1.007	1.781	0.039	2.542	0.627
218		0.1197	0.0861	0.0336	0.	1.005	1.763	0.149	2.422	0.638
220		0.1215	0.0854	0.0361	0.	1.002	1.720	0.097	2.172	0.659
221	0.0977	0.1225	0.0849	0.0375	0.	1.000	1.696	0.106	2.044	0.669
224		0.1251	0.0825	0.0425	0.	0.996	1.614	0.163	1.661	0.697
225	0.0955	0.1258	0.0814	0.0444	0.	0.994	1.584	0.087	1.536	0.706
231	0.1274	0.1248	0.0690	0.0558	0.	0.985	1.383	0.278	0.897	0.749
240	0.1340	0.1109	0.0634	0.0475	0.	0.971	1.079	0.087	0.744	0.782
247	0.0982	0.1059	0.0591	0.0467	0.0001	0.960	1.005	0.214	0.650	0.774
254	0.1117	0.1007	0.0555	0.0452	0.0001	0.949	0.935	0.079	0.580	0.734
268		0.0910	0.0507	0.0400	0.0003	0.927	0.800	0.164	0.500	0.680

A_{leaf}=0.0874 B_{stalk}=0.0808 C_{soil}=0.1849 D=5.0000 E=1.7340

CORRELATION COEFFICIENT=0.8955

MANHATTAN AGRICULTURAL EXPERIMENT

1980 SORGHUM S-32
13.0 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
158	0.0471	0.0397	0.0117	0.0006	0.0274	0.154	0.113	0.228	0.060	0.005
161	0.0457	0.0464	0.0205	0.0012	0.0247	0.245	0.141	0.243	0.110	0.009
165	0.0347	0.0504	0.0347	0.0030	0.0127	0.383	0.239	0.195	0.200	0.016
168	0.0617	0.0605	0.0504	0.0051	0.0050	0.493	0.347	0.141	0.320	0.035
170	0.0813	0.0712	0.0632	0.0067	0.0012	0.567	0.436	0.063	0.440	0.051
176	0.0977	0.1105	0.1002	0.0099	0.0003	0.778	0.723	0.229	1.068	0.108
178	0.1146	0.1181	0.1077	0.0103	0.0001	0.840	0.826	0.198	1.357	0.129
182	0.1175	0.1259	0.1150	0.0109	0.	0.943	1.035	0.120	1.943	0.175
189		0.1288	0.1184	0.0105	0.	1.026	1.307	0.074	2.853	0.264
190	0.1445	0.1297	0.1185	0.0112	0.	1.046	1.418	0.080	2.960	0.277
192	0.1349	0.1299	0.1187	0.0111	0.	1.046	1.500	0.052	3.152	0.303
196	0.1202	0.1301	0.1189	0.0111	0.	1.040	1.641	0.038	3.435	0.358
198	0.1265	0.1302	0.1190	0.0112	0.	1.037	1.700	0.032	3.522	0.385
199		0.1303	0.1190	0.0112	0.	1.035	1.725	0.030	3.551	0.399
204	0.1549	0.1308	0.1190	0.0118	0.	1.027	1.819	0.129	3.551	0.466
206	0.1327	0.1311	0.1190	0.0121	0.	1.024	1.839	0.062	3.484	0.493
210	0.1442	0.1318	0.1188	0.0130	0.	1.018	1.851	0.069	3.243	0.544
212		0.1322	0.1187	0.0136	0.	1.015	1.843	0.060	3.075	0.569
213	0.1315	0.1325	0.1186	0.0139	0.	1.013	1.835	0.052	2.980	0.581
217	0.1352	0.1334	0.1178	0.0156	0.	1.007	1.781	0.039	2.542	0.627
218		0.1336	0.1174	0.0161	0.	1.005	1.763	0.149	2.422	0.638
220		0.1338	0.1164	0.0174	0.	1.002	1.720	0.097	2.172	0.659
221	0.1091	0.1338	0.1157	0.0181	0.	1.000	1.696	0.106	2.044	0.669
224		0.1328	0.1124	0.0204	0.	0.996	1.614	0.163	1.661	0.697
225	0.1140	0.1321	0.1107	0.0213	0.	0.994	1.584	0.087	1.536	0.706
231	0.1169	0.1204	0.0937	0.0268	0.	0.985	1.383	0.278	0.897	0.749
240	0.1208	0.1088	0.0860	0.0228	0.	0.971	1.079	0.087	0.744	0.782
247	0.1125	0.1026	0.0802	0.0224	0.0001	0.960	1.005	0.214	0.650	0.774
254	0.1016	0.0969	0.0752	0.0216	0.0001	0.949	0.935	0.079	0.580	0.734
268		0.0881	0.0687	0.0192	0.0002	0.927	0.800	0.164	0.500	0.680

A_{leaf}=0.1193 B_{stalk}=0.0385 C_{soil}=0.1454 D=5.0000 E=1.7170

CORRELATION COEFFICIENT=0.9375

MANHATTAN AGRICULTURAL EXPERIMENT

1980 SORGHUM S-32
17.0 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
158	0.0452	0.0488	0.0087	0.0016	0.0386	0.154	0.113	0.228	0.060	0.005
161	0.0646	0.0536	0.0154	0.0030	0.0352	0.245	0.141	0.243	0.110	0.009
165	0.0417	0.0524	0.0263	0.0074	0.0186	0.383	0.239	0.195	0.200	0.016
168	0.0490	0.0592	0.0388	0.0128	0.0076	0.493	0.347	0.141	0.320	0.035
170	0.0843	0.0684	0.0493	0.0172	0.0019	0.567	0.436	0.063	0.440	0.051
176	0.1104	0.1098	0.0824	0.0269	0.0006	0.778	0.723	0.229	1.068	0.108
178	0.1104	0.1187	0.0900	0.0285	0.0002	0.840	0.826	0.198	1.357	0.129
182	0.1135	0.1290	0.0984	0.0306	0.	0.943	1.035	0.120	1.943	0.175
189		0.1330	0.1030	0.0300	0.	1.026	1.307	0.074	2.853	0.264
190	0.1259	0.1353	0.1033	0.0320	0.	1.046	1.418	0.080	2.960	0.277
192	0.1300	0.1355	0.1036	0.0319	0.	1.046	1.500	0.052	3.152	0.303
196	0.1303	0.1360	0.1040	0.0320	0.	1.040	1.641	0.038	3.435	0.358
198	0.1570	0.1363	0.1041	0.0322	0.	1.037	1.700	0.032	3.522	0.385
199		0.1365	0.1041	0.0324	0.	1.035	1.725	0.030	3.551	0.399
204	0.1611	0.1380	0.1041	0.0339	0.	1.027	1.819	0.129	3.551	0.466
206	0.1429	0.1389	0.1040	0.0348	0.	1.024	1.839	0.062	3.484	0.493
210	0.1365	0.1411	0.1038	0.0373	0.	1.018	1.851	0.069	3.243	0.544
212		0.1424	0.1035	0.0390	0.	1.015	1.843	0.060	3.075	0.569
213	0.1656	0.1432	0.1033	0.0399	0.	1.013	1.835	0.052	2.980	0.581
217	0.1663	0.1466	0.1021	0.0446	0.	1.007	1.781	0.039	2.542	0.627
218		0.1476	0.1016	0.0460	0.	1.005	1.763	0.049	2.422	0.638
220		0.1494	0.1002	0.0492	0.	1.002	1.720	0.097	2.172	0.659
221	0.1084	0.1503	0.0993	0.0510	0.	1.000	1.696	0.106	2.044	0.669
224		0.1523	0.0952	0.0570	0.	0.996	1.614	0.163	1.661	0.697
225	0.1259	0.1526	0.0934	0.0592	0.	0.994	1.584	0.087	1.536	0.706
231	0.1588	0.1477	0.0761	0.0716	0.	0.985	1.383	0.278	0.897	0.749
240	0.1387	0.1292	0.0690	0.0602	0.	0.971	1.079	0.087	0.744	0.782
247	0.1159	0.1226	0.0638	0.0586	0.0001	0.960	1.005	0.214	0.650	0.774
254	0.1303	0.1158	0.0595	0.0563	0.0001	0.949	0.935	0.079	0.580	0.734
268		0.1038	0.0539	0.0495	0.0004	0.927	0.800	0.164	0.500	0.680

A_{leaf}=0.1047 B_{stalk}=0.0938 C_{soil}=0.2014 D=5.0000 E=1.4460

CORRELATION COEFFICIENT=0.9025

MANHATTAN AGRICULTURAL EXPERIMENT

1980 SORGHUM S-32
35.6 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
158	0.0311	0.0406	0.0141	0.0005	0.0260	0.154	0.113	0.228	0.060	0.005
161	0.0617	0.0494	0.0249	0.0010	0.0234	0.245	0.141	0.243	0.110	0.009
165	0.0573	0.0570	0.0425	0.0025	0.0120	0.383	0.239	0.195	0.200	0.016
168	0.0644	0.0715	0.0625	0.0043	0.0047	0.493	0.347	0.141	0.320	0.035
170	0.0741	0.0862	0.0793	0.0058	0.0011	0.567	0.436	0.063	0.440	0.051
176	0.1556	0.1406	0.1313	0.0090	0.0003	0.778	0.723	0.229	1.068	0.108
178	0.1449	0.1526	0.1431	0.0095	0.0001	0.840	0.826	0.198	1.357	0.129
182		0.1659	0.1558	0.0101	0.	0.943	1.035	0.120	1.943	0.175
189		0.1725	0.1626	0.0099	0.	1.026	1.307	0.074	2.853	0.264
190	0.1758	0.1735	0.1629	0.0106	0.	1.046	1.418	0.080	2.960	0.277
192	0.1815	0.1740	0.1634	0.0105	0.	1.046	1.500	0.052	3.152	0.303
196	0.1641	0.1745	0.1640	0.0105	0.	1.040	1.641	0.038	3.435	0.358
198	0.2123	0.1747	0.1641	0.0106	0.	1.037	1.700	0.032	3.522	0.385
199		0.1748	0.1641	0.0107	0.	1.035	1.725	0.030	3.551	0.399
204	0.1871	0.1753	0.1641	0.0112	0.	1.027	1.819	0.129	3.551	0.466
206	0.1879	0.1755	0.1640	0.0115	0.	1.024	1.859	0.062	3.484	0.493
210	0.1538	0.1759	0.1636	0.0123	0.	1.018	1.851	0.069	3.243	0.544
212		0.1761	0.1633	0.0129	0.	1.015	1.843	0.060	3.075	0.569
213	0.1422	0.1762	0.1630	0.0132	0.	1.013	1.835	0.052	2.980	0.581
217	0.1718	0.1759	0.1612	0.0147	0.	1.007	1.781	0.039	2.542	0.627
218		0.1757	0.1605	0.0152	0.	1.005	1.763	0.149	2.422	0.638
220		0.1747	0.1584	0.0163	0.	1.002	1.720	0.097	2.172	0.659
221	0.1592	0.1740	0.1571	0.0169	0.	1.000	1.696	0.106	2.044	0.669
224		0.1699	0.1510	0.0189	0.	0.996	1.614	0.163	1.661	0.697
225	0.1770	0.1678	0.1482	0.0197	0.	0.994	1.584	0.087	1.536	0.706
231	0.1538	0.1454	0.1215	0.0239	0.	0.985	1.383	0.278	0.897	0.749
240	0.1374	0.1306	0.1105	0.0201	0.	0.971	1.079	0.087	0.744	0.782
247	0.1000	0.1220	0.1023	0.0196	0.0001	0.960	1.005	0.214	0.650	0.774
254	0.1303	0.1143	0.0954	0.0189	0.	0.949	0.935	0.079	0.580	0.734
268		0.1034	0.0866	0.0166	0.0002	0.927	0.800	0.164	0.500	0.680

A_{leaf}=0.1649 B_{stalk}=0.0318 C_{soil}=0.1371 D=5.5000 E=1.4880

CORRELATION COEFFICIENT=0.9478

MANHATTAN AGRICULTURAL EXPERIMENT

1980 SORGHUM S-33
8.6 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
158	0.0690	0.0489	0.0122	0.0010	0.0357	0.154	0.080	0.243	0.080	0.001
161	0.0372	0.0502	0.0187	0.0007	0.0308	0.241	0.037	0.225	0.129	0.003
163		0.0503	0.0277	0.0020	0.0205	0.305	0.088	0.188	0.203	0.005
165	0.0355	0.0530	0.0370	0.0039	0.0121	0.373	0.150	0.151	0.292	0.009
168	0.0479	0.0653	0.0505	0.0076	0.0072	0.480	0.259	0.169	0.453	0.024
170	0.0804	0.0709	0.0585	0.0105	0.0019	0.552	0.341	0.079	0.579	0.036
171	0.0813	0.0753	0.0622	0.0119	0.0012	0.587	0.383	0.065	0.647	0.042
176	0.0899	0.0958	0.0764	0.0188	0.0007	0.760	0.609	0.258	1.039	0.081
178	0.1102	0.1013	0.0802	0.0209	0.0002	0.822	0.703	0.142	1.220	0.099
182	0.0993	0.1096	0.0844	0.0252	0.	0.930	0.889	0.085	1.526	0.138
189	0.1288	0.1132	0.0891	0.0241	0.	1.037	1.189	0.102	2.512	0.215
190	0.1346	0.1140	0.0892	0.0248	0.	1.048	1.228	0.094	2.547	0.227
192	0.1114	0.1150	0.0892	0.0258	0.	1.040	1.301	0.063	2.583	0.251
196	0.1175	0.1172	0.0893	0.0279	0.	1.039	1.429	0.034	2.614	0.300
198	0.1368	0.1183	0.0893	0.0290	0.	1.038	1.482	0.037	2.612	0.325
199		0.1188	0.0893	0.0295	0.	1.038	1.506	0.037	2.607	0.337
204	0.1186	0.1212	0.0892	0.0320	0.	1.036	1.597	0.156	2.543	0.399
206	0.1045	0.1221	0.0891	0.0330	0.	1.035	1.627	0.092	2.502	0.424
210	0.1009	0.1236	0.0889	0.0346	0.	1.032	1.642	0.089	2.396	0.472
212	0.1156	0.1244	0.0888	0.0356	0.	1.030	1.649	0.078	2.333	0.496
213	0.1219	0.1245	0.0887	0.0358	0.	1.029	1.638	0.068	2.299	0.507
217	0.1315	0.1255	0.0883	0.0372	0.	1.026	1.606	0.044	2.152	0.551
218		0.1257	0.0881	0.0375	0.	1.025	1.594	0.188	2.113	0.561
220		0.1259	0.0878	0.0381	0.	1.022	1.565	0.090	2.032	0.582
221	0.1132	0.1260	0.0876	0.0383	0.	1.021	1.547	0.084	1.990	0.591
224	0.1294	0.1260	0.0870	0.0390	0.	1.018	1.488	0.126	1.863	0.619
225	0.1183	0.1259	0.0868	0.0391	0.	1.017	1.465	0.113	1.819	0.627
231	0.1390	0.1243	0.0848	0.0396	0.	1.008	1.311	0.288	1.560	0.670
240	0.1331	0.1185	0.0799	0.0386	0.	0.994	1.061	0.067	1.204	0.706
247	0.1102	0.1125	0.0752	0.0372	0.0001	0.981	0.910	0.208	0.993	0.704
254	0.1122	0.1096	0.0717	0.0378	0.0001	0.966	0.868	0.131	0.877	0.670
268		0.1045	0.0690	0.0354	0.0001	0.932	0.800	0.126	0.800	0.650

A_{leaf}=0.0901 B_{stalk}=0.0900 C_{soil}=0.1805 D=5.0000 E=1.8134

CORRELATION COEFFICIENT=0.9017

MANHATTAN AGRICULTURAL EXPERIMENT

1980 SORGHUM S-33
13.0 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
158	0.0430	0.0344	0.0129	0.0003	0.0213	0.154	0.080	0.243	0.000	0.001
161	0.0417	0.0390	0.0201	0.0002	0.0186	0.241	0.037	0.225	0.129	0.003
163		0.0438	0.0302	0.0005	0.0130	0.305	0.088	0.188	0.203	0.005
165	0.0324	0.0502	0.0412	0.0010	0.0080	0.373	0.150	0.151	0.292	0.009
168	0.0457	0.0653	0.0580	0.0021	0.0052	0.480	0.259	0.169	0.453	0.024
170	0.0741	0.0733	0.0689	0.0029	0.0015	0.552	0.341	0.079	0.579	0.036
171	0.0832	0.0783	0.0741	0.0033	0.0009	0.587	0.383	0.065	0.647	0.042
176	0.1091	0.1027	0.0964	0.0056	0.0007	0.760	0.609	0.258	1.039	0.081
178	0.1205	0.1100	0.1034	0.0064	0.0002	0.822	0.703	0.142	1.220	0.099
182	0.1200	0.1200	0.1121	0.0079	0.	0.930	0.889	0.085	1.526	0.138
189	0.1259	0.1328	0.1249	0.0079	0.	1.037	1.189	0.102	2.512	0.215
190	0.1340	0.1333	0.1251	0.0082	0.	1.048	1.228	0.094	2.547	0.227
192	0.1416	0.1338	0.1253	0.0085	0.	1.040	1.301	0.063	2.583	0.251
196	0.1324	0.1347	0.1255	0.0092	0.	1.039	1.429	0.034	2.614	0.300
198	0.1524	0.1350	0.1255	0.0096	0.	1.038	1.482	0.037	2.612	0.325
199		0.1352	0.1254	0.0097	0.	1.038	1.506	0.037	2.607	0.337
204	0.1493	0.1356	0.1251	0.0105	0.	1.036	1.597	0.156	2.543	0.399
206	0.1331	0.1357	0.1248	0.0109	0.	1.035	1.627	0.092	2.502	0.424
210	0.1368	0.1354	0.1241	0.0114	0.	1.032	1.642	0.089	2.396	0.472
212	0.1233	0.1352	0.1236	0.0117	0.	1.030	1.649	0.078	2.333	0.496
213	0.1148	0.1350	0.1233	0.0117	0.	1.029	1.638	0.068	2.299	0.507
217	0.1419	0.1341	0.1220	0.0121	0.	1.026	1.606	0.044	2.152	0.551
218		0.1337	0.1215	0.0122	0.	1.025	1.594	0.188	2.113	0.561
220		0.1329	0.1206	0.0123	0.	1.022	1.565	0.090	2.032	0.582
221	0.1242	0.1325	0.1201	0.0124	0.	1.021	1.547	0.084	1.990	0.591
224	0.1274	0.1309	0.1184	0.0125	0.	1.018	1.488	0.126	1.863	0.619
225	0.1227	0.1302	0.1177	0.0125	0.	1.017	1.465	0.113	1.819	0.627
231	0.1253	0.1253	0.1129	0.0124	0.	1.008	1.311	0.288	1.560	0.670
240	0.1081	0.1146	0.1029	0.0117	0.	0.994	1.061	0.067	1.204	0.706
247	0.1175	0.1054	0.0944	0.0110	0.0001	0.981	0.910	0.208	0.993	0.704
254	0.1081	0.0996	0.0886	0.0110	0.0001	0.966	0.868	0.131	0.877	0.670
268		0.0945	0.0842	0.0102	0.0001	0.932	0.800	0.126	0.800	0.650

A_{leaf}=0.1297 B_{stalk}=0.0220 C_{soil}=0.1032 D=5.0000 E=1.3090

CORRELATION COEFFICIENT=0.9571

MANHATTAN AGRICULTURAL EXPERIMENT

1980 SORGHUM S-33
17.0 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
158	0.0489	0.0381	0.0146	0.0004	0.0231	0.154	0.080	0.243	0.080	0.001
161	0.0468	0.0434	0.0227	0.0003	0.0204	0.241	0.037	0.225	0.129	0.003
163		0.0490	0.0342	0.0007	0.0141	0.305	0.088	0.188	0.203	0.005
165	0.0339	0.0566	0.0465	0.0014	0.0087	0.373	0.150	0.151	0.292	0.009
168	0.0490	0.0739	0.0654	0.0029	0.0056	0.430	0.259	0.169	0.453	0.024
170	0.0851	0.0832	0.0775	0.0040	0.0016	0.552	0.341	0.079	0.579	0.036
171	0.0891	0.0890	0.0833	0.0047	0.0010	0.587	0.383	0.065	0.647	0.042
176	0.1321	0.1166	0.1082	0.0077	0.0007	0.760	0.609	0.258	1.039	0.081
178	0.1318	0.1249	0.1159	0.0088	0.0002	0.822	0.703	0.142	1.220	0.099
182	0.1462	0.1363	0.1254	0.0109	0.	0.930	0.889	0.085	1.526	0.138
189	0.1517	0.1502	0.1392	0.0110	0.	1.037	1.189	0.102	2.512	0.215
190	0.1472	0.1508	0.1395	0.0113	0.	1.048	1.228	0.094	2.547	0.227
192	0.1560	0.1514	0.1397	0.0117	0.	1.040	1.301	0.063	2.583	0.251
196	0.1445	0.1526	0.1399	0.0127	0.	1.039	1.429	0.034	2.614	0.300
198	0.1671	0.1531	0.1399	0.0132	0.	1.038	1.482	0.037	2.612	0.325
199		0.1533	0.1398	0.0135	0.	1.038	1.506	0.037	2.607	0.337
204	0.1622	0.1540	0.1394	0.0146	0.	1.036	1.597	0.156	2.543	0.399
206	0.1476	0.1542	0.1392	0.0150	0.	1.035	1.627	0.092	2.502	0.424
210	0.1520	0.1541	0.1384	0.0157	0.	1.032	1.642	0.089	2.396	0.472
212	0.1581	0.1540	0.1379	0.0161	0.	1.030	1.649	0.078	2.333	0.496
213	0.1600	0.1537	0.1376	0.0162	0.	1.029	1.638	0.068	2.299	0.507
217	0.1596	0.1528	0.1361	0.0167	0.	1.026	1.606	0.044	2.152	0.551
218		0.1525	0.1357	0.0168	0.	1.025	1.594	0.188	2.113	0.561
220		0.1517	0.1347	0.0170	0.	1.022	1.565	0.090	2.032	0.582
221	0.1156	0.1512	0.1341	0.0171	0.	1.021	1.547	0.084	1.990	0.591
224	0.1377	0.1495	0.1322	0.0172	0.	1.018	1.488	0.126	1.863	0.619
225	0.1403	0.1488	0.1315	0.0173	0.	1.017	1.465	0.113	1.819	0.627
231	0.1507	0.1434	0.1262	0.0172	0.	1.008	1.311	0.288	1.560	0.670
240	0.1303	0.1315	0.1153	0.0162	0.	0.994	1.061	0.067	1.204	0.706
247	0.1175	0.1212	0.1059	0.0153	0.0001	0.981	0.910	0.208	0.993	0.704
254	0.1365	0.1148	0.0994	0.0153	0.0001	0.966	0.868	0.131	0.877	0.670
268		0.1089	0.0946	0.0141	0.0001	0.932	0.800	0.126	0.800	0.650

A_{leaf}=0.1443 B_{stalk}=0.0308 C_{soil}=0.1124 D=5.0000 E=1.2320

CORRELATION COEFFICIENT=0.9481

MANHATTAN AGRICULTURAL EXPERIMENT

1980 SORGHUM S-33
35.6 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
158	0.0352	0.0443	0.0155	0.	0.0288	0.154	0.080	0.243	0.080	0.001
161	0.0575	0.0496	0.0243	0.	0.0253	0.241	0.037	0.225	0.129	0.003
163		0.0564	0.0369	0.	0.0195	0.305	0.088	0.188	0.203	0.005
165	0.0662	0.0650	0.0508	0.	0.0142	0.373	0.150	0.151	0.292	0.009
168	0.0609	0.0863	0.0728	0.	0.0135	0.480	0.259	0.169	0.453	0.024
170	0.0920	0.0930	0.0875	0.	0.0055	0.552	0.341	0.079	0.579	0.036
171	0.1127	0.0989	0.0947	0.	0.0042	0.587	0.383	0.065	0.647	0.042
176	0.1770	0.1386	0.1275	0.	0.0111	0.760	0.609	0.258	1.039	0.081
178	0.1578	0.1437	0.1386	0.	0.0051	0.822	0.703	0.142	1.220	0.099
182		0.1554	0.1532	0.	0.0022	0.930	0.889	0.085	1.526	0.138
189	0.1828	0.1789	0.1779	0.	0.0009	1.037	1.189	0.102	2.512	0.215
190	0.1936	0.1793	0.1784	0.	0.0008	1.048	1.228	0.094	2.547	0.227
192	0.2075	0.1795	0.1789	0.	0.0005	1.040	1.301	0.063	2.583	0.251
196	0.2355	0.1796	0.1793	0.0001	0.0003	1.039	1.429	0.034	2.614	0.300
198	0.2244	0.1796	0.1793	0.0001	0.0003	1.038	1.482	0.037	2.612	0.325
199		0.1796	0.1792	0.0001	0.0003	1.038	1.506	0.037	2.607	0.337
204	0.1879	0.1798	0.1784	0.0001	0.0014	1.036	1.597	0.156	2.543	0.399
206	0.1824	0.1787	0.1778	0.0001	0.0008	1.035	1.627	0.092	2.502	0.424
210	0.1469	0.1771	0.1762	0.0001	0.0009	1.032	1.642	0.089	2.396	0.472
212	0.1259	0.1760	0.1751	0.0001	0.0009	1.030	1.649	0.078	2.333	0.496
213	0.1315	0.1753	0.1745	0.0001	0.0008	1.029	1.638	0.068	2.299	0.507
217	0.1390	0.1723	0.1717	0.0001	0.0006	1.026	1.606	0.044	2.152	0.551
218		0.1735	0.1708	0.0001	0.0026	1.025	1.594	0.188	2.113	0.561
220		0.1704	0.1690	0.0001	0.0014	1.022	1.565	0.090	2.032	0.582
221	0.1520	0.1694	0.1680	0.0001	0.0013	1.021	1.547	0.084	1.990	0.591
224	0.1449	0.1670	0.1646	0.0001	0.0023	1.018	1.488	0.126	1.863	0.619
225	0.1611	0.1656	0.1634	0.0001	0.0021	1.017	1.465	0.113	1.819	0.627
231	0.1531	0.1617	0.1545	0.0001	0.0071	1.008	1.311	0.288	1.560	0.670
240	0.1439	0.1402	0.1377	0.0001	0.0024	0.994	1.061	0.067	1.204	0.706
247	0.1227	0.1338	0.1243	0.0001	0.0094	0.981	0.910	0.208	0.993	0.704
254	0.1412	0.1223	0.1156	0.0001	0.0067	0.966	0.868	0.131	0.877	0.670
268		0.1161	0.1091	0.0001	0.0070	0.932	0.800	0.126	0.800	0.650

A_{leaf}=0.1914 B_{stalk}=0.0001 C_{soil}=0.1287 D=0.0001 E=1.0550

CORRELATION COEFFICIENT=0.8617

APPENDIX E - 1980 Corn Data

Observed values of the backscattering coefficients, predicted values, ground-truth values, and correlation between predicted and observed backscattering coefficients, and model values for three intensively measured corn fields.

MODEL EQUATION

$$\sigma^{o}_{pred} = \sigma^{o}_{leaf} + \sigma^{o}_{stalk} + \sigma^{o}_{soil}$$

$$= A_{leaf}\,(1 - e^{-E \cdot LAI})$$

$$+ \frac{B_{stalk} \cdot W \cdot H}{E \cdot LAI}\,(1 - e^{-E \cdot LAI})$$

$$+ C_{soil} \cdot m_s \cdot e^{-D \cdot W \cdot H}\, e^{E \cdot LAI}$$

Symbol	SI Units	Description
σ^{o}_{pred}	$m^2\ m^{-2}$	Predicted backscattering cross section coefficient
σ^{o}_{leaf}	$m^2\ m^{-2}$	Backscattering cross section coefficient for leaf contribution
σ^{o}_{stalk}	$m^2\ m^{-2}$	Backscattering cross section coefficient for stalk contribution
σ^{o}_{soil}	$m^2\ m^{-2}$	Backscattering cross section coefficient for soil contribution
LAI	$m^2\ m^{-2}$	Leaf Area Index
H	m	crop canopy height
W	$kg\ m^{-3}$	Volumetric normalized plant water content
m_s	$kg\ m^{-3}$	Volumetric soil moisture content
A_{leaf}	----	Empirical coefficient for leaf contribution to predicted radar backscatter
B_{stalk}	----	Empirical coefficient for stalk contribution to predicted radar backscatter
C_{soil}	----	Empirical coefficient for soil contribution to predicted radar backscatter
D	nepers $m\ kg^{-1}$	Empirical attenuation coefficient for attenuation due to plant water
E	nepers	Empirical attenuation constant for attenuation due to leaves
ρ	----	Correlation coefficient between predicted and observed backscatter coefficients

MANHATTAN AGRICULTURAL EXPERIMENT

1980 CORN C-11
8.6 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
158	0.0607	0.0724	0.0159	0.0001	0.0564	0.216	0.329	0.201	0.102	0.025
161	0.0724	0.0781	0.0439	0.0001	0.0340	0.374	0.440	0.163	0.323	0.031
165		0.1019	0.0744	0.0003	0.0272	0.660	0.597	0.208	0.67[illegible]	0.051
168	0.1014	0.0946	0.0908	0.0003	0.0035	0.748	0.718	0.040	0.965	0.074
170	0.1239	0.1014	0.0990	0.0003	0.0021	0.815	0.799	0.031	1.166	0.092
171		0.1053	0.1023	0.0004	0.0026	0.996	0.839	0.044	1.266	0.104
176	0.1306	0.1209	0.1137	0.0005	0.0068	1.227	1.037	0.224	1.770	0.163
178	0.1455	0.1199	0.1164	0.0005	0.0030	1.342	1.112	0.131	1.963	0.191
182	0.1355	0.1215	0.1199	0.0006	0.0010	1.543	1.255	0.070	2.326	0.253
189		0.1254	0.1243	0.0006	0.0005	2.013	1.470	0.148	3.439	0.379
190	0.1652	0.1253	0.1242	0.0007	0.0004	2.054	1.496	0.122	3.412	0.398
192	0.1315	0.1252	0.1242	0.0007	0.0003	2.136	1.544	0.092	3.368	0.439
196	0.1455	0.1251	0.1240	0.0009	0.0002	2.345	1.626	0.043	3.315	0.522
198	0.1333	0.1262	0.1240	0.0009	0.0013	2.346	1.659	0.332	3.298	0.567
199		0.1256	0.1240	0.0009	0.0007	2.347	1.672	0.191	3.291	0.587
204	0.1109	0.1253	0.1239	0.0009	0.0005	2.350	1.721	0.123	3.244	0.701
206	0.1009	0.1251	0.1238	0.0009	0.0003	2.371	1.729	0.075	3.214	0.747
210	0.1035	0.1250	0.1235	0.0010	0.0005	2.312	1.729	0.100	3.095	0.840
212		0.1247	0.1233	0.0010	0.0004	2.362	1.720	0.072	3.007	0.887
213	0.1064	0.1244	0.1231	0.0010	0.0003	2.386	1.713	0.046	2.955	0.910
217		0.1245	0.1222	0.0010	0.0013	2.258	1.670	0.159	2.711	1.003
218		0.1249	0.1219	0.0011	0.0020	2.393	1.656	0.215	2.644	1.027
220		0.1239	0.1210	0.0011	0.0018	2.378	1.624	0.159	2.486	1.073
221	0.0991	0.1229	0.1205	0.0012	0.0013	2.392	1.605	0.100	2.406	1.096
224		0.1216	0.1183	0.0012	0.0020	2.382	1.543	0.113	2.143	1.163
225	0.0938	0.1207	0.1174	0.0012	0.0021	2.387	1.520	0.102	2.051	1.185
231	0.1164	0.1202	0.1076	0.0014	0.0112	2.419	1.357	0.251	1.458	1.314
240	0.0562	0.0760	0.0663	0.0018	0.0080	2.419	1.056	0.054	0.563	1.486
247	0.0723	0.0679	0.0091	0.0018	0.0571	2.286	0.800	0.195	0.056	1.596
254	0.0530	0.0297	0.	0.0012	0.0285	2.183	0.553	0.089	0.	1.680
268		0.0444	0.	0.0005	0.0440	2.190	0.216	0.137	0.	1.680

A_{leaf}=0.1256 B_{stalk}=0.0010 C_{soil}=0.3222 D=0.0100 E=1.3312

CORRELATION COEFFICIENT=0.7876

MANHATTAN AGRICULTURAL EXPERIMENT

1980 CORN C-11
13.0 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
158	0.0516	0.0774	0.0181	0.0001	0.0592	0.216	0.329	0.201	0.102	0.025
161	0.0918	0.0892	0.0513	0.0001	0.0377	0.374	0.440	0.163	0.323	0.031
165		0.1233	0.0900	0.0003	0.0330	0.660	0.597	0.208	0.675	0.051
168	0.1368	0.1175	0.1126	0.0003	0.0046	0.748	0.718	0.040	0.965	0.074
170	0.1486	0.1279	0.1246	0.0004	0.0029	0.815	0.799	0.031	1.166	0.092
171		0.1338	0.1297	0.0005	0.0037	0.996	0.839	0.044	1.266	0.104
176	0.1849	0.1596	0.1483	0.0006	0.0108	1.227	1.037	0.224	1.770	0.163
178	0.1845	0.1589	0.1531	0.0006	0.0051	1.342	1.112	0.131	1.963	0.191
182	0.1679	0.1624	0.1599	0.0007	0.0018	1.543	1.255	0.070	2.326	0.253
189		0.1717	0.1698	0.0008	0.0012	2.013	1.470	0.148	3.439	0.379
190	0.1991	0.1715	0.1697	0.0008	0.0010	2.054	1.496	0.122	3.412	0.398
192	0.1945	0.1711	0.1695	0.0009	0.0008	2.136	1.544	0.092	3.368	0.439
196	0.1897	0.1706	0.1692	0.0010	0.0004	2.345	1.626	0.043	3.315	0.522
198	0.1828	0.1731	0.1691	0.0011	0.0030	2.346	1.659	0.332	3.298	0.567
199		0.1719	0.1681	0.0011	0.0017	2.347	1.672	0.191	3.291	0.587
204	0.1552	0.1711	0.1688	0.0011	0.0012	2.350	1.721	0.123	3.244	0.701
206	0.1648	0.1705	0.1686	0.0011	0.0007	2.371	1.729	0.075	3.214	0.747
210	0.1567	0.1702	0.1679	0.0012	0.0011	2.312	1.729	0.100	3.095	0.840
212		0.1694	0.1673	0.0012	0.0009	2.362	1.720	0.072	3.007	0.887
213	0.1403	0.1687	0.1669	0.0012	0.0006	2.386	1.713	0.046	2.955	0.910
217		0.1686	0.1647	0.0012	0.0027	2.258	1.670	0.159	2.711	1.003
218		0.1692	0.1640	0.0013	0.0039	2.393	1.656	0.215	2.644	1.027
220		0.1669	0.1622	0.0013	0.0034	2.378	1.624	0.159	2.486	1.073
221	0.1265	0.1648	0.1611	0.0014	0.0024	2.392	1.605	0.100	2.406	1.096
224		0.1618	0.1568	0.0014	0.0035	2.382	1.543	0.113	2.143	1.163
225	0.1205	0.1600	0.1550	0.0015	0.0035	2.387	1.520	0.102	2.051	1.185
231	0.1419	0.1562	0.1380	0.0017	0.0165	2.419	1.357	0.251	1.458	1.314
240	0.0690	0.0906	0.0793	0.0019	0.0094	2.419	1.056	0.054	0.563	1.486
247	0.0845	0.0713	0.0103	0.0018	0.0592	2.286	0.800	0.195	0.056	1.596
254	0.0551	0.0303	0.	0.0012	0.0291	2.183	0.553	0.089	0.	1.680
268		0.0454	0.	0.0005	0.0450	2.190	0.216	0.137	0.	1.680

A_{leaf}=0.1740 B_{stalk}=0.0010 C_{soil}=0.3295 D=0.0100 E=1.0745

CORRELATION COEFFICIENT=0.8726

MANHATTAN AGRICULTURAL EXPERIMENT

1980 CORN C-11
17.0 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
158	0.0759	0.0791	0.0156	0.0001	0.0634	0.216	0.329	0.201	0.102	0.025
161	0.0631	0.0883	0.0456	0.0001	0.0426	0.374	0.440	0.163	0.323	0.031
165		0.1239	0.0833	0.0003	0.0402	0.660	0.597	0.208	0.675	0.051
168	0.1112	0.1138	0.1075	0.0004	0.0060	0.748	0.718	0.040	0.965	0.074
170	0.1675	0.1256	0.1212	0.0004	0.0040	0.815	0.799	0.031	1.166	0.092
171		0.1329	0.1272	0.0005	0.0051	0.996	0.839	0.044	1.266	0.104
176	0.1622	0.1685	0.1513	0.0007	0.0166	1.227	1.037	0.224	1.770	0.163
178	0.2075	0.1671	0.1583	0.0008	0.0081	1.342	1.112	0.131	1.963	0.191
182	0.2037	0.1727	0.1687	0.0009	0.0031	1.543	1.255	0.070	2.326	0.253
189		0.1905	0.1870	0.0010	0.0024	2.013	1.470	0.148	3.439	0.379
190	0.2163	0.1898	0.1868	0.0011	0.0020	2.054	1.496	0.122	3.412	0.398
192	0.2056	0.1890	0.1863	0.0011	0.0016	2.136	1.544	0.092	3.368	0.439
196	0.2133	0.1877	0.1857	0.0013	0.0007	2.345	1.626	0.043	3.315	0.522
198	0.1950	0.1924	0.1855	0.0014	0.0056	2.346	1.659	0.332	3.298	0.567
199		0.1900	0.1854	0.0014	0.0032	2.347	1.672	0.191	3.291	0.587
204	0.2004	0.1884	0.1849	0.0014	0.0021	2.350	1.721	0.123	3.244	0.701
206	0.1832	0.1873	0.1845	0.0015	0.0013	2.371	1.729	0.075	3.214	0.747
210	0.1496	0.1864	0.1830	0.0015	0.0020	2.312	1.729	0.100	3.095	0.840
212		0.1848	0.1818	0.0015	0.0015	2.362	1.720	0.072	3.007	0.887
213	0.1600	0.1836	0.1810	0.0016	0.0010	2.386	1.713	0.046	2.955	0.910
217		0.1828	0.1769	0.0015	0.0043	2.258	1.670	0.159	2.711	1.003
218		0.1834	0.1757	0.0016	0.0060	2.393	1.656	0.215	2.644	1.027
220		0.1793	0.1725	0.0017	0.0051	2.378	1.624	0.159	2.486	1.073
221	0.1355	0.1758	0.1706	0.0017	0.0034	2.392	1.605	0.100	2.406	1.096
224		0.1704	0.1638	0.0018	0.0049	2.382	1.543	0.113	2.143	1.163
225	0.1233	0.1676	0.1611	0.0018	0.0048	2.387	1.520	0.102	2.051	1.185
231	0.1449	0.1590	0.1376	0.0019	0.0194	2.419	1.357	0.251	1.453	1.314
240	0.0543	0.0837	0.0725	0.0021	0.0092	2.419	1.056	0.054	0.563	1.486
247	0.0746	0.0641	0.0088	0.0018	0.0535	2.286	0.800	0.195	0.056	1.596
254	0.0689	0.0286	0.	0.0012	0.0274	2.183	0.553	0.089	0.	1.680
268		0.0456	0.	0.0005	0.0451	2.190	0.216	0.137	0.	1.680

A_{leaf}=0.1998 B_{stalk}=0.0010 C_{soil}=0.3450 D=0.0991 E=0.8000

CORRELATION COEFFICIENT=0.8681

MANHATTAN AGRICULTURAL EXPERIMENT

1980 CORN C-11
35.6 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
158	0.0561	0.0679	0.0200	0.0001	0.0478	0.216	0.329	0.201	0.102	0.025
161	0.0762	0.0881	0.0572	0.0001	0.0308	0.374	0.440	0.163	0.323	0.031
165		0.1290	0.1017	0.0003	0.0271	0.660	0.597	0.208	0.675	0.051
168	0.1663	0.1324	0.1283	0.0003	0.0038	0.748	0.718	0.040	0.965	0.074
170	0.1972	0.1455	0.1426	0.0004	0.0024	0.815	0.799	0.031	1.166	0.092
171		0.1524	0.1488	0.0005	0.0031	0.996	0.839	0.044	1.266	0.104
176	0.2178	0.1816	0.1720	0.0006	0.0090	1.227	1.037	0.224	1.770	0.163
178	0.1888	0.1832	0.1783	0.0007	0.0042	1.342	1.112	0.131	1.963	0.191
182		0.1894	0.1872	0.0008	0.0015	1.543	1.255	0.070	2.326	0.253
189		0.2027	0.2009	0.0008	0.0009	2.013	1.470	0.148	3.439	0.379
190	0.2328	0.2024	0.2007	0.0009	0.0008	2.054	1.496	0.122	3.412	0.398
192	0.2249	0.2019	0.2004	0.0009	0.0006	2.136	1.544	0.092	3.368	0.439
196	0.2323	0.2014	0.2000	0.0011	0.0003	2.345	1.626	0.043	3.315	0.522
198	0.2138	0.2032	0.1999	0.0011	0.0022	2.346	1.659	0.332	3.298	0.567
199		0.2022	0.1998	0.0012	0.0013	2.347	1.672	0.191	3.291	0.587
204	0.1722	0.2015	0.1994	0.0012	0.0009	2.350	1.721	0.123	3.244	0.701
206	0.1824	0.2009	0.1992	0.0012	0.0005	2.371	1.729	0.075	3.214	0.747
210	0.2188	0.2002	0.1981	0.0012	0.0008	2.312	1.729	0.100	3.095	0.840
212		0.1992	0.1972	0.0013	0.0006	2.362	1.720	0.072	3.007	0.887
213	0.1528	0.1984	0.1967	0.0013	0.0004	2.386	1.713	0.046	2.955	0.910
217		0.1969	0.1937	0.0013	0.0019	2.258	1.670	0.159	2.711	1.003
218		0.1969	0.1927	0.0014	0.0027	2.393	1.656	0.215	2.644	1.027
220		0.1940	0.1902	0.0014	0.0024	2.378	1.624	0.159	2.486	1.073
221	0.1660	0.1918	0.1887	0.0015	0.0016	2.392	1.605	0.100	2.406	1.096
224		0.1870	0.1831	0.0015	0.0025	2.382	1.543	0.113	2.143	1.163
225	0.1327	0.1847	0.1807	0.0015	0.0024	2.387	1.520	0.102	2.051	1.185
231	0.1442	0.1720	0.1591	0.0017	0.0112	2.419	1.357	0.251	1.458	1.314
240	0.0559	0.0975	0.0892	0.0020	0.0063	2.419	1.056	0.054	0.563	1.486
247	0.0655	0.0538	0.0113	0.0018	0.0407	2.286	0.800	0.195	0.056	1.596
254	0.0489	0.0222	0.	0.0012	0.0210	2.183	0.553	0.089	0.	1.680
268		0.0352	0.	0.0005	0.0347	2.190	0.216	0.137	0.	1.680

A_{leaf}=0.2076 B_{stalk}=0.0010 C_{soil}=0.2654 D=0.1000 E=0.9967

CORRELATION COEFFICIENT=0.8758

MANHATTAN AGRICULTURAL EXPERIMENT

1980 CORN C-12
8.6 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
158	0.0516	0.0714	0.0236	0.	0.0478	0.194	0.300	0.212	0.167	0.042
161	0.0566	0.0795	0.0430	0.	0.0365	0.354	0.411	0.188	0.327	0.043
165		0.0845	0.0701	0.	0.0143	0.671	0.566	0.095	0.601	0.057
168	0.0920	0.0951	0.0886	0.	0.0064	0.735	0.683	0.053	0.837	0.077
170	0.1312	0.1029	0.0994	0.	0.0035	0.818	0.760	0.034	1.003	0.093
176	0.1629	0.1385	0.1238	0.0001	0.0147	1.252	0.986	0.227	1.514	0.161
178	0.1581	0.1363	0.1295	0.0001	0.0067	1.419	1.057	0.121	1.680	0.189
182	0.1542	0.1407	0.1382	0.0001	0.0024	1.550	1.189	0.057	1.993	0.251
189		0.1574	0.1543	0.0001	0.0030	1.962	1.385	0.191	3.050	0.382
190	0.1766	0.1559	0.1543	0.0001	0.0015	2.037	1.409	0.097	3.046	0.402
192	0.1489	0.1552	0.1541	0.0001	0.0010	2.186	1.453	0.062	3.018	0.444
196	0.1734	0.1546	0.1540	0.0001	0.0005	2.353	1.525	0.030	3.013	0.533
198	0.1702	0.1566	0.1538	0.0001	0.0027	2.356	1.554	0.163	2.991	0.580
199		0.1568	0.1538	0.0001	0.0029	2.358	1.566	0.175	2.990	0.604
204	0.1514	0.1510	0.1521	0.0001	0.0028	2.368	1.608	0.144	2.825	0.726
206	0.1242	0.1536	0.1512	0.0001	0.0023	2.287	1.615	0.110	2.749	0.777
210	0.1371	0.1513	0.1488	0.0001	0.0023	2.318	1.612	0.095	2.562	0.880
212		0.1495	0.1475	0.0001	0.0019	2.270	1.603	0.070	2.470	0.932
213	0.1531	0.1481	0.1467	0.0001	0.0013	2.280	1.597	0.045	2.425	0.958
217	0.1371	0.1479	0.1444	0.0002	0.0034	2.322	1.559	0.107	2.287	1.063
218		0.1502	0.1432	0.0002	0.0068	2.355	1.546	0.204	2.223	1.089
220		0.1465	0.1403	0.0002	0.0060	2.422	1.517	0.158	2.086	1.142
221	0.1164	0.1427	0.1387	0.0002	0.0038	2.424	1.501	0.094	2.013	1.168
224		0.1386	0.1326	0.0002	0.0059	2.432	1.447	0.116	1.779	1.247
225	0.1079	0.1346	0.1301	0.0002	0.0044	2.427	1.427	0.080	1.698	1.272
231	0.1216	0.1310	0.1093	0.0002	0.0215	2.398	1.290	0.244	1.183	1.424
240	0.0646	0.0647	0.0547	0.0002	0.0098	2.398	1.046	0.055	0.437	1.636
247	0.0776	0.0560	0.0044	0.0002	0.0513	2.288	0.853	0.200	0.029	1.780
254	0.0468	0.0254	0.	0.0002	0.0252	2.218	0.684	0.096	0.	1.902
268		0.0314	0.	0.0001	0.0313	2.200	0.554	0.119	0.	2.052

A_{leaf}=0.1[illegible]0 B_{stalk}=0.0001 C_{soil}=0.2639 D=0.0001 E=0.9281

CORRELATION COEFFICIENT=0.8910

MANHATTAN AGRICULTURAL EXPERIMENT

1980 CORN C-12
13.0 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
158	0.0490	0.0865	0.0330	0.	0.0535	0.194	0.300	0.212	0.167	0.042
161	0.0851	0.0990	0.0593	0.	0.0397	0.354	0.411	0.188	0.327	0.043
165		0.1094	0.0946	0.	0.0148	0.671	0.566	0.095	0.601	0.057
168	0.1119	0.1239	0.1175	0.	0.0064	0.735	0.683	0.053	0.837	0.077
170	0.1762	0.1338	0.1304	0.	0.0034	0.818	0.760	0.034	1.003	0.093
176	0.2118	0.1707	0.1579	0.0001	0.0128	1.252	0.986	0.227	1.514	0.161
178	0.1858	0.1697	0.1639	0.0001	0.0057	1.419	1.057	0.121	1.680	0.189
182	0.1977	0.1746	0.1727	0.0001	0.0019	1.550	1.189	0.057	1.993	0.251
189		0.1892	0.1872	0.0001	0.0019	1.962	1.385	0.191	3.050	0.382
190	0.2355	0.1882	0.1871	0.0001	0.0010	2.037	1.409	0.097	3.046	0.402
192	0.2173	0.1877	0.1869	0.0001	0.0007	2.186	1.453	0.062	3.018	0.444
196	0.2133	0.1873	0.1869	0.0001	0.0003	2.353	1.525	0.030	3.013	0.533
198	0.1995	0.1886	0.1867	0.0001	0.0018	2.356	1.554	0.163	2.991	0.580
199		0.1887	0.1867	0.0001	0.0019	2.358	1.566	0.175	2.990	0.604
204	0.1702	0.1873	0.1853	0.0001	0.0019	2.368	1.608	0.144	2.825	0.726
206	0.1687	0.1863	0.1846	0.0001	0.0016	2.287	1.615	0.110	2.749	0.777
210	0.1702	0.1843	0.1825	0.0001	0.0017	2.318	1.612	0.095	2.562	0.880
212		0.1828	0.1813	0.0001	0.0014	2.270	1.603	0.070	2.470	0.932
213	0.1552	0.1817	0.1807	0.0001	0.0009	2.280	1.597	0.045	2.425	0.958
217	0.1403	0.1812	0.1785	0.0001	0.0025	2.322	1.559	0.107	2.287	1.063
218		0.1827	0.1774	0.0001	0.0052	2.355	1.546	0.204	2.223	1.089
220		0.1796	0.1747	0.0001	0.0047	2.422	1 517	0.158	2.086	1.142
221	0.1340	0.1763	0.1731	0.0001	0.0030	2.424	1.501	0.094	2.013	1.168
224		0.1720	0.1670	0.0002	0.0048	2.432	1.447	0.116	1.779	1.247
225	0.1349	0.1683	0.1645	0.0002	0.0037	2.427	1.427	0.080	1.698	1.272
231	0.1259	0.1619	0.1419	0.0002	0.0199	2.398	1.290	0.244	1.183	1.424
240	0.1143	0.0854	0.0748	0.0002	0.0104	2.398	1.046	0.055	0.437	1.636
247	0.1059	0.0655	0.0063	0.0002	0.0590	2.288	0.853	0.200	0.029	1.780
254	0.0372	0.0293	0.	0.0002	0.0292	2.218	0.684	0.096	0.	1.902
268		0.0363	0.	0.0001	0.0362	2.200	0.554	0.119	0.	2.052

A_{leaf}=0.1936 B_{stalk}=0.0001 C_{soil}=0.3050 D=0.0001 E=1.1165

CORRELATION COEFFICIENT=0.8223

MANHATTAN AGRICULTURAL EXPERIMENT

1980 CORN C-12
17.0 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
158	0.0502	0.0952	0.0425	0.0002	0.0525	0.194	0.300	0.212	0.167	0.042
161	0.1191	0.1122	0.0747	0.0004	0.0371	0.354	0.411	0.188	0.327	0.043
165		0.1290	0.1154	0.0008	0.0127	0.671	0.566	0.095	0.601	0.057
168	0.1449	0.1458	0.1398	0.0010	0.0051	0.735	0.683	0.053	0.837	0.077
170	0.1815	0.1564	0.1527	0.0011	0.0026	0.818	0.760	0.034	1.003	0.093
176	0.2080	0.1877	0.1777	0.0017	0.0083	1.252	0.986	0.227	1.514	0.161
178	0.2046	0.1880	0.1826	0.0019	0.0035	1.419	1.057	0.121	1.680	0.189
182	0.2371	0.1924	0.1893	0.0020	0.0011	1.550	1.189	0.057	1.993	0.251
189		0.2014	0.1985	0.0021	0.0008	1.962	1.385	0.191	3.050	0.382
190	0.2070	0.2011	0.1985	0.0022	0.0004	2.037	1.409	0.097	3.046	0.402
192	0.2178	0.2011	0.1984	0.0024	0.0003	2.186	1.453	0.062	3.018	0.444
196	0.2307	0.2013	0.1984	0.0027	0.0001	2.353	1.525	0.030	3.013	0.533
198	0.2382	0.2018	0.1983	0.0028	0.0007	2.356	1.554	0.163	2.991	0.580
199		0.2019	0.1983	0.0028	0.0008	2.358	1.566	0.175	2.990	0.604
204	0.2366	0.2014	0.1975	0.0031	0.0008	2.368	1.608	0.144	2.825	0.726
206	0.1879	0.2009	0.1971	0.0031	0.0007	2.287	1.615	0.110	2.749	0.777
210	0.1581	0.2000	0.1959	0.0033	0.0008	2.318	1.612	0.095	2.562	0.880
212		0.1991	0.1951	0.0033	0.0007	2.270	1.603	0.070	2.470	0.932
213	0.1633	0.1986	0.1947	0.0034	0.0005	2.280	1.597	0.045	2.425	0.958
217	0.1493	0.1982	0.1933	0.0036	0.0013	2.322	1.559	0.107	2.287	1.063
218		0.1990	0.1926	0.0037	0.0027	2.355	1.546	0.204	2.223	1.089
220		0.1972	0.1907	0.0039	0.0026	2.422	1.517	0.158	2.086	1.142
221	0.1432	0.1953	0.1896	0.0040	0.0017	2.424	1.501	0.094	2.013	1.168
224		0.1922	0.1851	0.0043	0.0029	2.432	1.447	0.116	1.779	1.247
225	0.1581	0.1897	0.1831	0.0043	0.0023	2.427	1.427	0.080	1.698	1.272
231	0.1845	0.1829	0.1636	0.0050	0.0143	2.398	1.299	0.244	1.183	1.424
240	0.1127	0.1086	0.0930	0.0062	0.0094	2.398	1.046	0.055	0.437	1.636
247	0.0912	0.0749	0.0082	0.0063	0.0603	2.288	0.853	0.200	0.029	1.780
254	0.0661	0.0351	0.	0.0050	0.0301	2.218	0.684	0.096	0.	1.902
268		0.0413	0.	0.0040	0.0373	2.200	0.554	0.119	0.	2.052

A_{leaf}=0.2012 B_{stalk}=0.0033 C_{soil}=0.3144 D=0.0001 E=1.4182

CORRELATION COEFFICIENT=0.8337

MANHATTAN AGRICULTURAL EXPERIMENT

1980 CORN C-12
35.6 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
158	0.0347	0.0518	0.0331	0.0013	0.0175	0.194	0.300	0.212	0.167	0.042
161	0.0661	0.0750	0.0593	0.0029	0.0129	0.354	0.411	0.188	0.327	0.043
165		0.1056	0.0943	0.0065	0.0048	0.671	0.566	0.095	0.601	0.057
168	0.1191	0.1265	0.1168	0.0076	0.0020	0.735	0.683	0.053	0.837	0.077
170	0.1462	0.1392	0.1294	0.0087	0.0011	0.818	0.760	0.034	1.003	0.093
176	0.2163	0.1737	0.1559	0.0138	0.0040	1.252	0.986	0.227	1.514	0.161
178		0.1791	0.1617	0.0157	0.0018	1.419	1.057	0.121	1.680	0.189
182		0.1876	0.1699	0.0171	0.0006	1.550	1.189	0.057	1.993	0.251
189		0.2017	0.1834	0.0178	0.0006	1.962	1.385	0.191	3.050	0.382
190	0.2203	0.2024	0.1834	0.0188	0.0003	2.037	1.409	0.097	3.046	0.402
192	0.2377	0.2043	0.1832	0.0210	0.0002	2.186	1.453	0.062	3.018	0.444
196	0.2323	0.2070	0.1831	0.0237	0.0001	2.353	1.525	0.030	3.013	0.533
198	0.2138	0.2079	0.1830	0.0244	0.0005	2.356	1.554	0.163	2.991	0.580
199		0.2081	0.1830	0.0246	0.0006	2.358	1.566	0.175	2.990	0.604
204	0.1941	0.2089	0.1817	0.0266	0.0006	2.368	1.608	0.144	2.825	0.726
206	0.1995	0.2079	0.1810	0.0264	0.0005	2.287	1.615	0.110	2.749	0.777
210	0.1815	0.2080	0.1791	0.0284	0.0005	2.318	1.612	0.095	2.562	0.880
212		0.2069	0.1780	0.0285	0.0004	2.270	1.603	0.070	2.470	0.932
213	0.1820	0.2067	0.1774	0.0290	0.0003	2.280	1.597	0.045	2.425	0.958
217	0.1738	0.2064	0.1754	0.0302	0.0008	2.322	1.559	0.107	2.287	1.063
218		0.2070	0.1744	0.0311	0.0016	2.355	1.546	0.204	2.223	1.089
220		0.2062	0.1719	0.0329	0.0014	2.422	1.517	0.158	2.086	1.142
221	0.2128	0.2048	0.1704	0.0335	0.0009	2.424	1.501	0.094	2.013	1.168
224		0.2015	0.1646	0.0354	0.0015	2.432	1.447	0.116	1.779	1.247
225	0.1936	0.1993	0.1622	0.0360	0.0011	2.427	1.427	0.080	1.698	1.272
231	0.1675	0.1868	0.1405	0.0400	0.0063	2.398	1.290	0.244	1.183	1.424
240	0.1324	0.1247	0.0747	0.0466	0.0034	2.398	1.046	0.055	0.437	1.636
247	0.0773	0.0710	0.0063	0.0453	0.0193	2.288	0.853	0.200	0.029	1.780
254	0.0678	0.0454	0.	0.0359	0.0096	2.218	0.684	0.096	0.	1.902
268		0.0407	0.	0.0288	0.0119	2.200	0.554	0.119	0.	2.052

A_{leaf}=0.1890 B_{stalk}=0.0236 C_{soil}=0.1000 D=0.0001 E=1.1501

CORRELATION COEFFICIENT=0.9415

MANHATTAN AGRICULTURAL EXPERIMENT

1980 CORN C-13
8.6 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
158	0.0525	0.0624	0.0222	0.	0.0402	0.237	0.315	0.218	0.181	0.036
161	0.0513	0.0760	0.0497	0.	0.0262	0.392	0.475	0.188	0 463	0.047
163		0.0836	0.0670	0.	0.0166	0.624	0.599	0.149	0.690	0.060
165	0.0933	0.0917	0.0821	0.	0.0096	0.678	0.738	0.110	0.941	0.076
168	0.1076	0.1028	0.1000	0.	0.0028	0.780	0.974	0.048	1.349	0.106
170	0.1368	0.1108	0.1088	0.	0.0020	0.808	1.149	0.044	1.634	0.130
171	0.1245	0.1138	0.1124	0.0001	0.0014	1.001	1.166	0.036	1.777	0.144
176	0.1459	0.1291	0.1244	0.0001	0.0046	1.263	1.394	0.239	2.494	0.218
178	0.1459	0.1300	0.1272	0.0001	0.0027	1.407	1.478	0.188	2.768	0.252
182	0.1592	0.1318	0.1307	0.0001	0.0010	1.496	1.631	0.107	3.273	0.327
189	0.1718	0.1353	0.1345	0.0001	0.0007	2.063	1.846	0.248	4.457	0.479
190	0.1722	0.1351	0.1345	0.0001	0.0005	2.060	1.871	0.189	4.446	0.500
192	0.1358	0.1349	0.1344	0.0001	0.0004	2.054	1.915	0.136	4.424	0.543
196	0.1542	0.1346	0.1343	0.0001	0.0001	2.347	1.984	0.043	4.356	0.637
198	0.1374	0.1357	0.1343	0.0001	0.0014	2.343	2.008	0.433	4.327	0.685
199		0.1351	0.1342	0.0001	0.0008	2.235	2.017	0.237	4.289	0.709
204	0.1465	0.1350	0.1341	0.0001	0.0008	2.170	2.038	0.228	4.235	0.831
206	0.1062	0.1345	0.1339	0.0001	0.0005	2.339	2.034	0.133	4.140	0.880
210	0.1125	0.1337	0.1331	0.0001	0.0004	2.305	2.006	0.088	3.863	0.975
212		0.1332	0.1326	0.0001	0.0005	2.384	1.982	0.092	3.684	1.022
213	0.1094	0.1329	0.1321	0.0001	0.0006	2.351	1.968	0.096	3.574	1.046
217	0.0980	0.1351	0.1299	0.0001	0.0050	2.300	1.895	0.491	3.137	1.136
218		0.1329	0.1291	0.0001	0.0036	2.326	1.871	0.316	3.009	1.157
220	0.1062	0.1312	0.1271	0.0001	0.0039	2.352	1.824	0.267	2.754	1.200
221	0.1000	0.1288	0.1258	0.0002	0.0029	2.345	1.798	0.173	2.616	1.220
224		0.1249	0.1205	0.0002	0.0042	2.285	1.712	0.164	2.204	1.281
225	0.0946	0.1230	0.1183	0.0002	0.0046	2.350	1.681	0.157	2.064	1.297
231	0.1071	0.1176	0.0954	0.0002	0.0221	2.359	1.473	0.335	1.227	1.402
240	0.0447	0.0413	0.0307	0.0002	0.0103	2.359	1.116	0.061	0.260	1.511
247	0.0809	0.0523	0.0098	0.0002	0.0423	2.356	0.832	0.207	0.077	1.550
254	0.0347	0.0231	0.	0.0001	0.0229	2.356	0.577	0.104	0.	1.541
268		0.0363	0.	0.0001	0.0362	2.199	0.309	0.165	0.	1.500

A_{leaf}=0.1360 B_{stalk}=0.0001 C_{soil}=0.2200 D=0.0001 E=0.9810

CORRELATION COEFFICIENT=0.8122

MANHATTAN AGRICULTURAL EXPERIMENT

1980 CORN C-13
13.0 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
158	0.0708	0.0738	0.0251	0.	0.0486	0.237	0.315	0.218	0.181	0.036
161	0.0617	0.0887	0.0569	0.	0.0318	0.392	0.475	0.188	0.463	0.047
163		0.0970	0.0772	0.	0.0198	0.624	0.599	0.149	0.690	0.060
165	0.1172	0.1067	0.0953	0.	0.0114	0.678	0.738	0.110	0.941	0.076
168	0.1276	0.1207	0.1173	0.	0.0033	0.780	0.974	0.048	1.349	0.106
170	0.1603	0.1309	0.1285	0.	0.0023	0.808	1.149	0.044	1.634	0.130
171	0.1432	0.1348	0.1332	0.0001	0.0016	1.001	1.166	0.036	1.777	0.144
176	0.1726	0.1541	0.1492	0.0001	0.0048	1.263	1.394	0.239	2.494	0.218
178	0.1644	0.1559	0.1531	0.0001	0.0028	1.407	1.478	0.188	2.768	0.252
182	0.1694	0.1591	0.1581	0.0001	0.0009	1.496	1.631	0.107	3.273	0.327
189	0.1778	0.1645	0.1639	0.0001	0.0006	2.063	1.846	0.248	4.457	0.479
190	0.1871	0.1644	0.1638	0.0001	0.0004	2.060	1.871	0.189	4.446	0.500
192	0.1782	0.1642	0.1638	0.0001	0.0003	2.054	1.915	0.136	4.424	0.543
196	0.1905	0.1638	0.1636	0.0001	0.0001	2.347	1.984	0.043	4.356	0.637
198	0.1435	0.1646	0.1635	0.0001	0.0010	2.343	2.008	0.433	4.327	0.685
199		0.1641	0.1634	0.0001	0.0006	2.235	2.017	0.237	4.289	0.709
204	0.1503	0.1639	0.1632	0.0001	0.0006	2.170	2.038	0.228	4.235	0.831
206	0.1549	0.1633	0.1629	0.0001	0.0003	2.339	2.034	0.133	4.140	0.880
210	0.1637	0.1622	0.1617	0.0001	0.0003	2.305	2.006	0.088	3.863	0.975
212		0.1613	0.1608	0.0001	0.0004	2.384	1.982	0.092	3.684	1.022
213	0.1538	0.1608	0.1602	0.0001	0.0004	2.351	1.968	0.096	3.574	1.046
217	0.1327	0.1605	0.1570	0.0001	0.0034	2.300	1.895	0.491	3.137	1.136
218		0.1584	0.1558	0.0001	0.0024	2.326	1.871	0.316	3.009	1.157
220	0.1406	0.1557	0.1529	0.0002	0.0026	2.352	1.824	0.267	2.754	1.200
221	0.1455	0.1532	0.1511	0.0002	0.0019	2.345	1.798	0.173	2.616	1.220
224		0.1469	0.1439	0.0002	0.0028	2.285	1.712	0.164	2.204	1.281
225	0.1135	0.1441	0.1409	0.0002	0.0031	2.350	1.681	0.157	2.064	1.297
231	0.0904	0.1270	0.1116	0.0002	0.0152	2.359	1.473	0.335	1.227	1.402
240	0.0537	0.0428	0.0349	0.0002	0.0077	2.359	1.116	0.061	0.260	1.511
247	0.0791	0.0467	0.0111	0.0002	0.0354	2.356	0.832	0.207	0.077	1.550
254	0.0324	0.0215	0.	0.0001	0.0214	2.356	0.577	0.104	0.	1.541
268		0.0386	0.	0.0001	0.0385	2.199	0.309	0.165	0.	1.500

A_{leaf}=0.1669 B_{stalk}=0.0001 C_{soil}=0.2660 D=0.1912 E=0.9000

CORRELATION COEFFICIENT=0.9018

MANHATTAN AGRICULTURAL EXPERIMENT

1980 CORN C-13
17.0 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
158	0.0759	0.0814	0.0281	0.	0.0533	0.237	0.315	0.218	0.181	0.036
161	0.0912	0.0981	0.0636	0.	0.0345	0.392	0.475	0.188	0.463	0.047
163		0.1075	0.0864	0.	0.0211	0.624	0.599	0.149	0.690	0.060
165	0.1268	0.1187	0.1067	0.	0.0120	0.678	0.738	0.110	0.941	0.076
168	0.1285	0.1347	0.1313	0.	0.0034	0.780	0.974	0.048	1.349	0.106
170	0.1600	0.1461	0.1438	0.	0.0023	0.808	1.149	0.044	1.634	0.130
171	0.1567	0.1506	0.1490	0.0001	0.0015	1.001	1.166	0.036	1.777	0.144
176	0.1963	0.1715	0.1669	0.0001	0.0045	1.263	1.394	0.239	2.494	0.218
178	0.2061	0.1739	0.1713	0.0001	0.0025	1.407	1.478	0.188	2.768	0.252
182	0.2099	0.1778	0.1769	0.0001	0.0008	1.496	1.631	0.107	3.273	0.327
189	0.2388	0.1839	0.1833	0.0001	0.0004	2.063	1.846	0.248	4.457	0.479
190	0.2223	0.1837	0.1833	0.0001	0.0003	2.060	1.871	0.189	4.446	0.500
192	0.1910	0.1836	0.1832	0.0001	0.0002	2.054	1.915	0.136	4.424	0.543
196	0.1959	0.1832	0.1830	0.0001	0.0001	2.347	1.984	0.043	4.356	0.637
198	0.1927	0.1837	0.1829	0.0001	0.0007	2.343	2.008	0.433	4.327	0.685
199		0.1833	0.1828	0.0001	0.0004	2.235	2.017	0.237	4.289	0.709
204	0.1726	0.1831	0.1826	0.0001	0.0004	2.170	2.038	0.228	4.235	0.831
206	0.1622	0.1826	0.1822	0.0001	0.0002	2.339	2.034	0.133	4.140	0.880
210	0.1483	0.1813	0.1809	0.0001	0.0002	2.305	2.006	0.088	3.863	0.975
212		0.1803	0.1799	0.0001	0.0003	2.384	1.982	0.092	3.684	1.022
213	0.1416	0.1797	0.1792	0.0001	0.0003	2.351	1.968	0.096	3.574	1.046
217	0.1368	0.1782	0.1756	0.0001	0.0025	2.300	1.895	0.491	3.137	1.136
218		0.1762	0.1743	0.0001	0.0018	2.326	1.871	0.316	3.009	1.157
220	0.1333	0.1731	0.1711	0.0002	0.0019	2.352	1.824	0.267	2.754	1.200
221	0.1542	0.1706	0.1690	0.0002	0.0014	2.345	1.798	0.173	2.616	1.220
224		0.1634	0.1610	0.0002	0.0022	2.285	1.712	0.164	2.204	1.281
225	0.1355	0.1601	0.1576	0.0002	0.0023	2.350	1.681	0.157	2.064	1.297
231	0.1315	0.1371	0.1249	0.0002	0.0120	2.359	1.473	0.335	1.227	1.402
240	0.0355	0.0459	0.0390	0.0002	0.0066	2.359	1.116	0.061	0.260	1.511
247	0.0573	0.0450	0.0124	0.0002	0.0324	2.356	0.832	0.207	0.077	1.550
254	0.0295	0.0209	0.	0.0001	0.0208	2.356	0.577	0.104	0.	1.541
268		0.0399	0.	0.0001	0.0398	2.299	0.309	0.165	0.	1.500

A_{leaf}=0.1867 B_{stalk}=0.0001 C_{soil}=0.2937 D=0.2863 E=0.9000

CORRELATION COEFFICIENT=0.8914

MANHATTAN AGRICULTURAL EXPERIMENT

1980 CORN C-13
35.6 GHz VV

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
158	0.0676	0.0735	0.0372	0.	0.0363	0.237	0.315	0.218	0.181	0.036
161	0.0708	0.1071	0.0837	0.	0.0234	0.392	0.475	0.188	0.463	0.047
163		0.1275	0.1130	0.	0.0144	0.624	0.599	0.149	0.690	0.060
165	0.1648	0.1470	0.1388	0.	0.0082	0.678	0.738	0.110	0.941	0.076
168	0.1910	0.1719	0.1695	0.	0.0023	0.780	0.974	0.048	1.349	0.106
170	0.2270	0.1864	0.1848	0.	0.0016	0.808	1.149	0.044	1.634	0.130
171	0.2296	0.1922	0.1911	0.0001	0.0011	1.001	1.166	0.036	1.777	0.144
176	0.2275	0.2156	0.2122	0.0001	0.0033	1.263	1.394	0.239	2.494	0.218
178	0.2541	0.2191	0.2171	0.0001	0.0019	1.407	1.478	0.188	2.768	0.252
182		0.2241	0.2234	0.0001	0.0006	1.496	1.631	0.107	3.273	0.327
189	0.2767	0.2308	0.2303	0.0001	0.0004	2.063	1.846	0.248	4.457	0.479
190	0.2477	0.2307	0.2303	0.0001	0.0003	2.060	1.871	0.189	4.446	0.500
192	0.2630	0.2305	0.2302	0.0001	0.0002	2.054	1.915	0.136	4.424	0.543
196	0.2844	0.2302	0.2300	0.0001	0.0001	2.347	1.984	0.043	4.356	0.637
198	0.2291	0.2306	0.2299	0.0001	0.0006	2.343	2.008	0.433	4.327	0.685
199		0.2302	0.2298	0.0001	0.0004	2.235	2.017	0.237	4.289	0.709
204	0.1722	0.2300	0.2296	0.0001	0.0004	2.170	2.038	0.228	4.235	0.831
206	0.2399	0.2295	0.2292	0.0001	0.0002	2.339	2.034	0.133	4.140	0.880
210	0.2070	0.2281	0.2278	0.0001	0.0002	2.305	2.006	0.088	3.863	0.975
212		0.2271	0.2267	0.0001	0.0003	2.384	1.982	0.092	3.684	1.022
213	0.1959	0.2264	0.2260	0.0001	0.0003	2.351	1.968	0.096	3.574	1.046
217	0.1901	0.2246	0.2220	0.0001	0.0024	2.300	1.895	0.491	3.137	1.136
218		0.2224	0.2205	0.0001	0.0017	2.326	1.871	0.316	3.009	1.157
220	0.1832	0.2190	0.2169	0.0002	0.0019	2.352	1.824	0.267	2.754	1.200
221	0.1622	0.2161	0.2146	0.0002	0.0014	2.345	1.798	0.173	2.616	1.220
224		0.2076	0.2053	0.0002	0.0021	2.285	1.712	0.164	2.204	1.281
225	0.1489	0.2037	0.2013	0.0002	0.0023	2.350	1.681	0.157	2.064	1.297
231	0.1698	0.1735	0.1616	0.0002	0.0117	2.359	1.473	0.335	1.227	1.402
240	0.0501	0.0580	0.0516	0.0002	0.0062	2.359	1.116	0.061	0.260	1.511
247	0.0614	0.0447	0.0165	0.0002	0.0280	2.356	0.832	0.207	0.077	1.550
254	0.0436	0.0169	0.	0.0001	0.0167	2.356	0.577	0.104	0.	1.541
268		0.0296	0.	0.0001	0.0295	2.199	0.309	0.165	0.	1.500

A_{leaf}=0.2335 B_{stalk}=0.0001 C_{soil}=0.2000 D=0.1622 E=0.9584

CORRELATION COEFFICIENT=0.8375

MANHATTAN AGRICULTURAL EXPERIMENT

1980 CORN C-11
8.6 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
158	0.0579	0.0842	0.0151	0.0001	0.0690	0.216	0.329	0.201	0.102	0.025
161	0.0778	0.0839	0.0420	0.0001	0.0418	0.374	0.440	0.163	0.323	0.031
165		0.1054	0.0714	0.0003	0.0337	0.660	0.597	0.208	0.675	0.051
168	0.1007	0.0920	0.0873	0.0003	0.0044	0.748	0.718	0.040	0.965	0.074
170	0.1161	0.0983	0.0953	0.0003	0.0027	0.815	0.799	0.031	1.166	0.092
171		0.1023	0.0985	0.0004	0.0033	0.996	0.839	0.044	1.266	0.104
176	0.1365	0.1189	0.1098	0.0005	0.0086	1.227	1.037	0.224	1.770	0.162
178	0.1327	0.1169	0.1125	0.0005	0.0039	1.342	1.112	0.131	1.963	0.191
182	0.1365	0.1179	0.1160	0.0006	0.0013	1.543	1.255	0.070	2.326	0.253
189		0.1218	0.1205	0.0007	0.0006	2.013	1.470	0.148	3.439	0.379
190	0.1503	0.1217	0.1205	0.0007	0.0005	2.054	1.496	0.122	3.412	0.398
192	0.1365	0.1216	0.1204	0.0007	0.0004	2.136	1.544	0.092	3.368	0.439
196	0.1368	0.1214	0.1203	0.0009	0.0002	2.345	1.626	0.043	3.315	0.522
198	0.1374	0.1228	0.1203	0.0009	0.0017	2.346	1.659	0.332	3.298	0.567
199		0.1221	0.1202	0.0009	0.0010	2.347	1.672	0.191	3.291	0.587
204	0.1047	0.1217	0.1201	0.0009	0.0007	2.350	1.721	0.123	3.244	0.701
206	0.1040	0.1215	0.1201	0.0010	0.0004	2.371	1.729	0.075	3.214	0.747
210	0.1104	0.1214	0.1198	0.0010	0.0007	2.312	1.729	0.100	3.095	0.840
212		0.1210	0.1195	0.0010	0.0005	2.362	1.720	0.072	3.007	0.887
213	0.0923	0.1207	0.1193	0.0010	0.0004	2.386	1.713	0.046	2.955	0.910
217		0.1211	0.1184	0.0010	0.0017	2.258	1.670	0.159	2.711	1.003
218		0.1217	0.1180	0.0011	0.0026	2.393	1.656	0.215	2.644	1.027
220		0.1206	0.1171	0.0011	0.0023	2.378	1.624	0.159	2.486	1.073
221	0.0923	0.1194	0.1166	0.0012	0.0016	2.392	1.605	0.100	2.406	1.096
224		0.1183	0.1145	0.0012	0.0026	2.382	1.543	0.113	2.143	1.153
225	0.0853	0.1174	0.1135	0.0013	0.0027	2.387	1.520	0.102	2.051	1.185
231	0.1175	0.1194	0.1037	0.0015	0.0142	2.419	1.357	0.251	1.458	1.314
240	0.0631	0.0752	0.0635	0.0018	0.0099	2.419	1.056	0.054	0.563	1.486
247	0.0931	0.0801	0.0086	0.0018	0.0697	2.286	0.800	0.195	0.056	1.596
254	0.0676	0.0359	0.	0.0012	0.0347	2.183	0.553	0.089	0.	1.680
268		0.0541	0.	0.0005	0.0536	2.190	0.216	0.137	0.	1.680

A_{leaf}=0.1219 B_{stalk}=0.0010 C_{soil}=0.3927 D=0.0100 E=1.3501

CORRELATION COEFFICIENT=0.6942

MANHATTAN AGRICULTURAL EXPERIMENT

1980 CORN C-11
13.0 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
158	0.0706	0.0918	0.0156	0.0001	0.0761	0.216	0.329	0.201	0.102	0.025
161	0.0916	0.0933	0.0444	0.0001	0.0487	0.374	0.440	0.163	0.323	0.031
165		0.1211	0.0782	0.0003	0.0427	0.660	0.597	0.208	0.675	0.051
168	0.1138	0.1042	0.0979	0.0003	0.0060	0.748	0.718	0.040	0.965	0.074
170	0.1390	0.1126	0.1084	0.0004	0.0038	0.815	0.799	0.031	1.166	0.092
171		0.1182	0.1129	0.0005	0.0043	0.996	0.839	0.044	1.266	0.104
176	0.1954	0.1441	0.1293	0.0006	0.0142	1.227	1.037	0.224	1.770	0.163
178	0.1578	0.1410	0.1336	0.0006	0.0067	1.342	1.112	0.131	1.963	0.191
182	0.1445	0.1428	0.1397	0.0007	0.0024	1.543	1.255	0.070	2.326	0.253
189		0.1509	0.1485	0.0008	0.0016	2.013	1.470	0.148	3.439	0.379
190	0.1941	0.1506	0.1484	0.0008	0.0013	2.054	1.496	0.122	3.412	0.398
192	0.1778	0.1502	0.1482	0.0009	0.0010	2.136	1.544	0.092	3.368	0.439
196	0.1726	0.1495	0.1480	0.0010	0.0005	2.345	1.626	0.043	3.315	0.522
198	0.1675	0.1530	0.1479	0.0011	0.0040	2.346	1.659	0.332	3.298	0.567
199		0.1513	0.1479	0.0011	0.0023	2.347	1.672	0.191	3.291	0.587
204	0.1256	0.1503	0.1476	0.0011	0.0016	2.350	1.721	0.123	3.244	0.701
206	0.1384	0.1496	0.1475	0.0012	0.0010	2.371	1.729	0.075	3.214	0.747
210	0.1197	0.1495	0.1468	0.0012	0.0015	2.312	1.729	0.100	3.095	0.840
212		0.1487	0.1462	0.0012	0.0012	2.362	1.720	0.072	3.007	0.887
213	0.1109	0.1479	0.1459	0.0012	0.0008	2.386	1.713	0.046	2.955	0.910
217		0.1488	0.1440	0.0012	0.0036	2.258	1.670	0.159	2.711	1.003
218		0.1499	0.1433	0.0013	0.0052	2.393	1.656	0.215	2.644	1.027
220		0.1476	0.1417	0.0014	0.0046	2.378	1.624	0.159	2.486	1.073
221	0.1040	0.1452	0.1407	0.0014	0.0031	2.392	1.605	0.100	2.406	1.096
224		0.1430	0.1369	0.0014	0.0047	2.382	1.543	0.113	2.143	1.163
225	0.1045	0.1414	0.1353	0.0015	0.0047	2.387	1.520	0.102	2.051	1.185
231	0.1262	0.1436	0.1202	0.0017	0.0217	2.419	1.357	0.251	1.458	1.314
240	0.0723	0.0829	0.0688	0.0019	0.0122	2.419	1.056	0.054	0.563	1.486
247	0.0944	0.0868	0.0089	0.0018	0.0761	2.286	0.800	0.195	0.056	1.596
254	0.0622	0.0386	0.	0.0012	0.0374	2.183	0.553	0.089	0.	1.680
268		0.0582	0.	0.0005	0.0577	2.190	0.216	0.137	0.	1.680

A_{leaf}=0.1524 B_{stalk}=0.0020 C_{soil}=0.4230 D=0.0100 E=1.0656

CORRELATION COEFFICIENT=0.7322

MANHATTAN AGRICULTURAL EXPERIMENT

1980 CORN C-11
17.0 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
158	0.0653	0.0801	0.0143	0.0001	0.0658	0.216	0.329	0.201	0.102	0.025
161	0.0759	0.0862	0.0416	0.0001	0.0444	0.374	0.440	0.163	0.323	0.031
165		0.1188	0.0762	0.0003	0.0424	0.660	0.597	0.208	0.675	0.051
168	0.0977	0.1049	0.0982	0.0004	0.0063	0.748	0.718	0.040	0.965	0.074
170	0.1439	0.1154	0.1107	0.0004	0.0043	0.815	0.799	0.031	1.166	0.092
171		0.1223	0.1163	0.0005	0.0055	0.996	0.839	0.044	1.266	0.104
176	0.1486	0.1571	0.1382	0.0007	0.0182	1.227	1.037	0.224	1.770	0.163
178	0.1879	0.1543	0.1446	0.0008	0.0090	1.342	1.112	0.131	1.963	0.191
182	0.2023	0.1585	0.1542	0.0009	0.0035	1.543	1.255	0.070	2.326	0.253
189		0.1748	0.1709	0.0010	0.0029	2.013	1.470	0.148	3.439	0.379
190	0.2009	0.1741	0.1706	0.0011	0.0024	2.054	1.496	0.122	3.412	0.398
192	0.1879	0.1732	0.1702	0.0011	0.0019	2.136	1.544	0.092	3.368	0.439
196	0.2032	0.1719	0.1697	0.0013	0.0009	2.345	1.626	0.043	3.315	0.522
198	0.2070	0.1778	0.1695	0.0014	0.0069	2.346	1.659	0.332	3.298	0.567
199		0.1748	0.1694	0.0014	0.0040	2.347	1.672	0.191	3.291	0.587
204	0.1811	0.1730	0.1689	0.0014	0.0026	2.350	1.721	0.123	3.244	0.701
206	0.1603	0.1717	0.1686	0.0015	0.0017	2.371	1.729	0.075	3.214	0.747
210	0.1483	0.1711	0.1672	0.0015	0.0024	2.312	1.729	0.100	3.095	0.840
212		0.1695	0.1661	0.0015	0.0019	2.362	1.720	0.072	3.007	0.887
213	0.1377	0.1682	0.1654	0.0016	0.0012	2.386	1.713	0.046	2.955	0.910
217		0.1685	0.1617	0.0015	0.0053	2.258	1.670	0.159	2.711	1.003
218		0.1697	0.1605	0.0016	0.0075	2.393	1.656	0.215	2.644	1.027
220		0.1656	0.1576	0.0017	0.0063	2.378	1.624	0.159	2.486	1.073
221	0.1071	0.1619	0.1559	0.0017	0.0042	2.392	1.605	0.100	2.406	1.096
224		0.1574	0.1497	0.0018	0.0060	2.382	1.543	0.113	2.143	1.163
225	0.1057	0.1548	0.1472	0.0018	0.0058	2.387	1.520	0.102	2.051	1.185
231	0.1236	0.1510	0.1257	0.0019	0.0234	2.419	1.357	0.251	1.458	1.314
240	0.0621	0.0790	0.0662	0.0021	0.0107	2.419	1.056	0.054	0.563	1.486
247	0.0865	0.0701	0.0080	0.0018	0.0602	2.286	0.800	0.195	0.056	1.596
254	0.0703	0.0311	0.	0.0012	0.0299	2.183	0.553	0.089	0.	1.680
268		0.0482	0.	0.0005	0.0477	2.190	0.216	0.137	0.	1.680

A_{leaf}=0.1826 B_{stalk}=0.0010 C_{soil}=0.3567 D=0.0529 E=0.8000

CORRELATION COEFFICIENT=0.8178

C-3

MANHATTAN AGRICULTURAL EXPERIMENT

1980 CORN C-11
35.6 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
158	0.0573	0.0780	0.0204	0.0001	0.0575	0.216	0.329	0.201	0.102	0.025
161	0.0863	0.0955	0.0584	0.0001	0.0370	0.374	0.440	0.163	0.323	0.031
165		0.1364	0.1037	0.0003	0.0325	0.660	0.597	0.208	0.675	0.051
168	0.1710	0.1357	0.1308	0.0003	0.0046	0.748	0.718	0.040	0.965	0.074
170	0.1991	0.1487	0.1454	0.0004	0.0029	0.815	0.799	0.031	1.166	0.092
171		0.1558	0.1516	0.0005	0.0037	0.996	0.839	0.044	1.266	0.104
176	0.2203	0.1864	0.1751	0.0006	0.0107	1.227	1.037	0.224	1.770	0.163
178	0.2344	0.1871	0.1815	0.0007	0.0050	1.342	1.112	0.131	1.963	0.191
182		0.1930	0.1904	0.0007	0.0018	1.543	1.255	0.070	2.326	0.253
189		0.2062	0.2042	0.0008	0.0011	2.013	1.470	0.148	3.439	0.379
190	0.2270	0.2058	0.2040	0.0009	0.0009	2.054	1.496	0.122	3.412	0.398
192	0.2254	0.2054	0.2037	0.0009	0.0007	2.136	1.544	0.092	3.368	0.439
196	0.2612	0.2048	0.2033	0.0011	0.0003	2.345	1.626	0.043	3.315	0.522
198	0.2223	0.2070	0.2032	0.0011	0.0026	2.346	1.659	0.332	3.298	0.567
199		0.2058	0.2031	0.0011	0.0015	2.347	1.672	0.191	3.291	0.587
204	0.1786	0.2050	0.2028	0.0012	0.0010	2.350	1.721	0.123	3.244	0.701
206	0.2109	0.2044	0.2025	0.0012	0.0006	2.371	1.729	0.075	3.214	0.747
210	0.1981	0.2036	0.2014	0.0012	0.0010	2.312	1.729	0.100	3.095	0.840
212		0.2026	0.2006	0.0013	0.0008	2.362	1.720	0.072	3.007	0.887
213	0.1459	0.2018	0.2000	0.0013	0.0005	2.386	1.713	0.046	2.955	0.910
217		0.2006	0.1970	0.0013	0.0023	2.258	1.670	0.159	2.711	1.003
218		0.2007	0.1960	0.0014	0.0033	2.393	1.656	0.215	2.644	1.027
220		0.1978	0.1935	0.0014	0.0029	2.378	1.624	0.159	2.486	1.073
221	0.1374	0.1954	0.1920	0.0014	0.0019	2.392	1.605	0.100	2.406	1.096
224		0.1907	0.1863	0.0015	0.0029	2.382	1.543	0.113	2.143	1.163
225	0.1233	0.1884	0.1839	0.0015	0.0029	2.387	1.520	0.102	2.051	1.185
231	0.1409	0.1771	0.1620	0.0017	0.0134	2.419	1.357	0.251	1.458	1.314
240	0.0627	0.1005	0.0910	0.0020	0.0076	2.419	1.056	0.054	0.563	1.486
247	0.0783	0.0623	0.0116	0.0018	0.0489	2.286	0.800	0.195	0.056	1.596
254	0.0579	0.0265	0.	0.0012	0.0253	2.183	0.553	0.089	0.	1.680
268		0.0422	0.	0.0005	0.0418	2.190	0.216	0.137	0.	1.680

A_{leaf}=0.2109 B_{stalk}=0.0010 C_{soil}=0.3193 D=0.1000 E=1.0022

CORRELATION COEFFICIENT=0.8196

MANHATTAN AGRICULTURAL EXPERIMENT

1980 CORN C-12
8.6 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
158	0.0562	0.0877	0.0242	0.	0.0635	0.194	0.300	0.212	0.167	0.042
161	0.0813	0.0912	0.0437	0.	0.0475	0.354	0.411	0.188	0.327	0.043
165		0.0883	0.0703	0.	0.0180	0.671	0.566	0.095	0.601	0.057
168	0.0946	0.0956	0.0877	0.	0.0079	0.735	0.683	0.053	0.837	0.07?
170	0.1358	0.1020	0.0977	0.	0.0042	0.818	0.760	0.034	1.003	0.093
176	0.1588	0.1358	0.1193	0.0001	0.0164	1.252	0.986	0.227	1.514	0.161
178	0.1560	0.1316	0.1242	0.0001	0.0074	1.419	1.057	0.121	1.680	0.189
182	0.1321	0.1339	0.1313	0.0001	0.0025	1.550	1.189	0.057	1.993	0.251
189		0.1464	0.1436	0.0001	0.0027	1.962	1.385	0.191	3.050	0.382
190	0.1690	0.1451	0.1436	0.0001	0.0014	2.037	1.409	0.097	3.046	0.402
192	0.1528	0.1444	0.1434	0.0001	0.0009	2 186	1.453	0.062	3.018	0.444
196	0.1626	0.1439	0.1434	0.0001	0.0004	2.353	1.525	0.030	3.013	0.533
198	0.1706	0.1458	0.1432	0.0001	0.0025	2.356	1.554	0.163	2.991	0.580
199		0.1460	0.1432	0.0001	0.0027	2.358	1.566	0.175	2.990	0.604
204	0.1343	0.1447	0.1420	0.0001	0.0026	2.368	1.608	0.144	2.825	0.726
206	0.1315	0.1436	0.1414	0.0001	0.0022	2.287	1.615	0.110	2.749	0.777
210	0.1175	0.1420	0.1396	0.0001	0.0023	2.318	1.612	0.095	2.562	0.880
212		0.1405	0.1385	0.0001	0.0018	2.270	1.603	0.070	2.470	0.932
213	0.1365	0.1394	0.1380	0.0001	0.0012	2.280	1.597	0.045	2.425	0.958
217	0.1324	0.1398	0.1362	0.0001	0.0034	2.322	1.559	0.107	2.287	1.063
218		0.1424	0.1353	0.0001	0 0070	2.355	1.546	0.204	2.223	1.089
220		0.1394	0.1330	0.0001	0.0063	2.422	1.517	0.158	2.086	1.142
221	0.1045	0.1359	0.1317	0.0002	0.0040	2.424	1.501	0.094	2.013	1.168
224		0.1332	0.1267	0.0002	0.0063	2.432	1.447	0.116	1.779	1.247
225	0.0980	0.1296	0.1247	0.0002	0.0048	2.427	1.427	0.080	1.698	1.272
231	0.1052	0.1319	0.1066	0.0002	0.0251	2.398	1.290	0.244	1.183	1.424
240	0.0741	0.0680	0.0553	0.0002	0.0125	2.398	1.046	0.055	0.437	1.636
247	0.1021	0.0742	0.0046	0.0002	0.0694	2.288	0.853	0 200	0.029	1.780
254	0.0562	0.0344	0.	0.0002	0.0343	2.218	0.684	0.096	0.	1.902
268		0.0426	0.	0.0001	0.0425	2.200	0.554	0.119	0.	2.052

A_{leaf}=0.1496 B_{stalk}=0.0001 C_{soil}=0.3582 D=0.0001 E=1.0555

CORRELATION COEFFICIENT=0.7908

MANHATTAN AGRICULTURAL E.PERIMENT

1980 CORN C-12
13.0 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
158	0.0537	0.0891	0.0274	0.	0.0617	0.194	0.300	0.212	0.167	0.042
161	0.0891	0.0964	0.0497	0.0001	0.0467	0.354	0.411	0.188	0.327	0.043
165		0.0987	0.0805	0.0001	0.0180	0.671	0.566	0.095	0.601	0.057
168	0.1007	0.1093	0.1012	0.0002	0.0080	0.735	0.683	0.053	0.837	0.077
170	0.1365	0.1176	0.1131	0.0002	0.0044	0.818	0.760	0.034	1.003	0.093
176	0.1770	0.1573	0.1395	0.0003	0.0175	1.252	0.986	0.227	1.514	0.161
178	0.1824	0.1539	0.1456	0.0003	0.0079	1.419	1.057	0.121	1.680	0.189
182	0.1941	0.1578	0.1547	0.0004	0.0027	1.550	1.189	0.057	1.993	0.251
189		0.1746	0.1709	0.0004	0.0032	1.962	1.385	0.191	3.050	0.382
190	0.1963	0.1730	0.1709	0.0004	0.0016	2.037	1.409	0.097	3.046	0.402
192	0.1910	0.1722	0.1707	0.0005	0.0011	2.186	1.453	0.062	3.018	0.444
196	0.1888	0.1717	0.1706	0.0005	0.0005	2.353	1.525	0.030	3.013	0.533
198	0.1910	0.1739	0.1704	0.0005	0.0029	2.356	1.554	0.163	2.991	0.580
199		0.1741	0.1704	0.0005	0.0031	2.358	1.566	0.175	2.990	0.604
204	0.1476	0.1724	0.1688	0.0006	0.0030	2.368	1.608	0.144	2.825	0.726
206	0.1849	0.1710	0.1679	0.0006	0.0025	2.287	1.615	0.110	2.749	0.777
210	0.1486	0.1687	0.1655	0.0006	0.0026	2.318	1.612	0.095	2.562	0.880
212		0.1668	0.1641	0.0006	0.0021	2.270	1.603	0.070	2.470	0.932
213	0.1435	0.1654	0.1634	0.0006	0.0014	2.280	1.597	0.045	2.425	0.958
217	0.1250	0.1655	0.1610	0.0007	0.0038	2.322	1.559	0.107	2.287	1.063
218		0.1683	0.1598	0.0007	0.0078	2.355	1.546	0.204	2.223	1.089
220		0.1645	0.1569	0.0007	0.0069	2.422	1.517	0.158	2.086	1.142
221	0.1222	0.1603	0.1552	0.0007	0.0044	2.424	1.501	0.094	2.013	1.168
224		0.1564	0.1488	0.0008	0.0069	2.432	1.447	0.116	1.779	1.247
225	0.1202	0.1521	0.1462	0.0008	0.0051	2.427	1.427	0.080	1.698	1.272
231	0.1400	0.1508	0.1239	0.0008	0.0261	2.398	1.290	0.244	1.183	1.424
240	0.1000	0.0764	0.0631	0.0009	0.0124	2.398	1.046	0.055	0.437	1.636
247	0.1047	0.0728	0.0051	0.0009	0.0668	2.288	0.853	0.200	0.029	1.780
254	0.0398	0.0336	0.	0.0007	0.0329	2.218	0.684	0.096	0.	1.902
268		0.0414	0.	0.0006	0.0408	2.200	0.554	0.119	0.	2.052

A_{leaf}=0.1798 B_{stalk}=0.0045 C_{soil}=0.3441 D=0.0001 E=0.9886

CORRELATION COEFFICIENT=0.8305

MANHATTAN AGRICULTURAL EXPERIMENT

1980 CORN C-12
17.0 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
158	0.0724	0.0913	0.0266	0.	0.0647	0.194	0.300	0.212	0.167	0.042
161	0.0676	0.0994	0.0489	0.	0.0504	0.354	0.411	0.188	0.327	0.043
165		0.1016	0.0811	0.	0.0205	0.671	0.566	0.095	0.601	0.057
168	0.1049	0.1132	0.1036	0.	0.0095	0.735	0.683	0.053	0.837	0.077
170	0.1432	0.1225	0.1172	0.	0.0053	0.818	0.760	0.034	1.003	0.093
176	0.2188	0.1726	0.1490	0.0001	0.0235	1.252	0.986	0.227	1.514	0.161
178	0.1888	0.1680	0.1569	0.0001	0.0110	1.419	1.057	0.121	1.680	0.189
182	0.2239	0.1732	0.1691	0.0001	0.0040	1.550	1.189	0.057	1.993	0.251
189		0.1995	0.1936	0.0001	0.0058	1.962	1.385	0.191	3.050	0.382
190	0.1879	0.1966	0.1935	0.0001	0.0029	2.037	1.409	0.097	3.046	0.402
192	0.2104	0.1952	0.1931	0.0001	0.0019	2.186	1.453	0.062	3.018	0.444
196	0.2004	0.1941	0.1931	0.0001	0.0009	2.353	1.525	0.030	3.013	0.533
198	0.2366	0.1980	0.1927	0.0001	0.0052	2.356	1.554	0.163	2.991	0.580
199		0.1984	0.1927	0.0001	0.0056	2.358	1.566	0.175	2.990	0.604
204	0.2249	0.1954	0.1900	0.0002	0.0052	2.368	1.608	0.144	2.825	0.726
206	0.1683	0.1930	0.1886	0.0001	0.0042	2.287	1.615	0.110	2.749	0.777
210	0.1479	0.1892	0.1848	0.0002	0.0042	2.318	1.612	0.095	2.562	0.880
212		0.1863	0.1827	0.0002	0.0034	2.270	1.603	0.070	2.470	0.932
213	0.1683	0.1841	0.1817	0.0002	0.0022	2.280	1.597	0.045	2.425	0.958
217	0.1303	0.1843	0.1781	0.0002	0.0060	2.322	1.559	0.107	2.287	1.063
218		0.1885	0.1763	0.0002	0.0120	2.355	1.546	0.204	2.223	1.089
220		0.1827	0.1722	0.0002	0.0104	2.422	1.517	0.158	2.086	1.142
221	0.1412	0.1765	0.1698	0.0002	0.0065	2.424	1.501	0.094	2.013	1.168
224		0.1710	0.1611	0.0002	0.0097	2.432	1.447	0.116	1.779	1.247
225	0.1390	0.1650	0.1577	0.0002	0.0072	2.427	1.427	0.080	1.698	1.272
231	0.1596	0.1631	0.1299	0.0002	0.0331	2.398	1.290	0.244	1.183	1.424
240	0.1007	0.0766	0.0627	0.0002	0.0137	2.398	1.046	0.055	0.437	1.636
247	0.0832	0.0734	0.0049	0.0002	0.0683	2.288	0.853	0.200	0.029	1.780
254	0.0661	0.0336	0.	0.0002	0.0335	2.218	0.684	0.096	0.	1.902
268		0.0416	0.	0.0001	0.0415	2.200	0.554	0.119	0.	2.052

A_{leaf}=0.2120 B_{stalk}=0.0001 C_{soil}=0.3496 D=0.0001 E=0.8022

CORRELATION COEFFICIENT=0.8636

MANHATTAN AGRICULTURAL EXPERIMENT

1980 CORN C-12
35.6 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
158	0.0436	0.0526	0.0341	0.0014	0.0170	0.194	0.300	0.212	0.167	0.042
161	0.0575	0.0759	0.0604	0.0033	0.0122	0.354	0.411	0.188	0.327	0.043
165		0.1061	0.0945	0.0073	0.0043	0.671	0.566	0.095	0.601	0.057
168	0.1331	0.1257	0.1155	0.0084	0.0018	0.735	0.683	0.053	0.837	0.077
170	0.1545	0.1374	0.1269	0.0096	0.0009	0.818	0.760	0.034	1.003	0.093
176	0.1871	0.1678	0.1498	0.0148	0.0032	1.252	0.986	0.227	1.514	0.161
178		0.1727	0.1545	0.0168	0.0014	1.419	1.057	0.121	1.680	0.189
182		0.1796	0.1611	0.0181	0.0004	1.550	1.189	0.057	1.993	0.251
189		0.1896	0.1708	0.0185	0.0004	1.962	1.385	0.191	3.050	0.382
190	0.2153	0.1905	0.1708	0.0196	0.0002	2.037	1.409	0.097	3.046	0.402
192	0.2265	0.1926	0.1706	0.0218	0.0001	2.186	1.453	0.062	3.018	0.444
196	0.2163	0.1954	0.1706	0.0247	0.0001	2.353	1.525	0.030	3.013	0.533
198	0.2056	0.1962	0.1705	0.0254	0.0003	2.356	1.554	0.163	2.991	0.580
199		0.1965	0.1705	0.0256	0.0004	2.358	1.566	0.175	2.990	0.604
204	0.1828	0.1978	0.1697	0.0278	0.0004	2.368	1.608	0.144	2.825	0.726
206	0.2009	0.1971	0.1692	0.0276	0.0003	2.287	1.615	0.110	2.749	0.777
210	0.1585	0.1980	0.1679	0.0298	0.0003	2.318	1.612	0.095	2.562	0.880
212		0.1973	0.1671	0.0299	0.0003	2.270	1.603	0.070	2.470	0.932
213	0.1694	0.1973	0.1667	0.0304	0.0002	2.280	1.597	0.045	2.425	0.958
217	0.1782	0.1975	0.1652	0.0318	0.0005	2.322	1.559	0.107	2.287	1.063
218		0.1983	0.1644	0.0327	0.0011	2.355	1.546	0.204	2.223	1.089
220		0.1984	0.1626	0.0348	0.0010	2.422	1.517	0.158	2.086	1.142
221	0.1991	0.1976	0.1614	0.0355	0.0007	2.424	1.501	0.094	2.013	1.168
224		0.1958	0.1569	0.0377	0.0011	2.432	1.447	0.116	1.779	1.247
225	0.2004	0.1943	0.1550	0.0384	0.0009	2.427	1.427	0.080	1.698	1.272
231	0.1542	0.1855	0.1367	0.0435	0.0052	2.398	1.290	0.244	1.183	1.424
240	0.1276	0.1314	0.0756	0.0527	0.0031	2.398	1.046	0.055	0.437	1.636
247	0.0873	0.0785	0.0065	0.0527	0.0192	2.288	0.853	0.200	0.029	1.780
254	0.0834	0.0514	0.	0.0418	0.0096	2.218	0.684	0.096	0.	1.902
268		0.0455	0.	0.0336	0.0119	2.200	0.554	0.119	0.	2.052

A_{leaf}=0.1741 B_{stalk}=0.0275 C_{soil}=0.1000 D=0.0001 E=1.3022

CORRELATION COEFFICIENT=0.9235

MANHATTAN AGRICULTURAL EXPERIMENT

1980 CORN C-13
8.6 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
158	0.0692	0.0850	0.0263	0.	0.0587	0.237	0.315	0.218	0.181	0.036
161	0.0804	0.0906	0.0563	0.	0.0343	0.392	0.475	0.188	0.463	0.047
163		0.0932	0.0733	0.	0.0199	0.624	0.599	0.149	0.690	0.060
165	0.0977	0.0973	0.0868	0.	0.0104	0.678	0.738	0.110	0.941	0.076
168	0.1062	0.1036	0.1010	0.	0.0026	0.780	0.974	0.048	1.349	0.106
170	0.1265	0.1088	0.1071	0.	0.0016	0.808	1.149	0.044	1.634	0.130
171	0.1000	0.1105	0.1094	0.	0.0011	1.001	1.166	0.036	1.777	0.144
176	0.1349	0.1187	0.1160	0.	0.0027	1.263	1.394	0.239	2.494	0.218
178	0.1449	0.1187	0.1172	0.0001	0.0015	1.407	1.478	0.188	2.768	0.252
182	0.1432	0.1190	0.1185	0.0001	0.0004	1.496	1.631	0.107	3.273	0.327
189	0.1384	0.1199	0.1196	0.0001	0.0002	2.063	1.846	0.248	4.457	0.479
190	0.1233	0.1198	0.1196	0.0001	0.0001	2.060	1.871	0.189	4.446	0.500
192	0.1225	0.1198	0.1196	0.0001	0.0001	2.054	1.915	0.136	4.424	0.543
196	0.1233	0.1197	0.1196	0.0001	0.	2.347	1.984	0.043	4.356	0.637
198	0.1268	0.1200	0.1196	0.0001	0.0004	2.343	2.008	0.433	4.327	0.685
199		0.1199	0.1196	0.0001	0.0002	2.235	2.017	0.237	4.289	0.709
204	0.1164	0.1198	0.1195	0.0001	0.0002	2.170	2.038	0.228	4.235	0.831
206	0.1069	0.1197	0.1195	0.0001	0.0002	2.339	2.034	0.133	4.140	0.880
210	0.1151	0.1195	0.1193	0.0001	0.0002	2.305	2.006	0.088	3.863	0.975
212		0.1194	0.1191	0.0001	0.0002	2.384	1.982	0.092	3.684	1.022
213	0.1054	0.1193	0.1190	0.0001	0.0002	2.351	1.968	0.096	3.574	1.046
217	0.0970	0.1207	0.1183	0.0001	0.0023	2.300	1.895	0.491	3.137	1.136
218		0.1198	0.1179	0.0001	0.0018	2.326	1.871	0.316	3.009	1.157
220	0.1109	0.1194	0.1171	0.0001	0.0021	2.352	1.824	0.267	2.754	1.200
221	0.1076	0.1183	0.1166	0.0001	0.0017	2.345	1.798	0.173	2.616	1.220
224		0.1169	0.1140	0.0001	0.0028	2.285	1.712	0.164	2.204	1.281
225	0.0964	0.1161	0.1128	0.0001	0.0032	2.350	1.681	0.157	2.064	1.297
231	0.1107	0.1192	0.0976	0.0002	0.0215	2.359	1.473	0.335	1.227	1.402
240	0.0490	0.0508	0.0359	0.0002	0.0146	2.359	1.116	0.061	0.260	1.511
247	0.0957	0.0763	0.0119	0.0002	0.0642	2.356	0.832	0.207	0.077	1.550
254	0.0436	0.0361	0.	0.0001	0.0359	2.356	0.577	0.104	0.	1.541
268		0.0568	0.	0.0001	0.0567	2.199	0.309	0.165	0.	1.500

A_{leaf}=0.1199 B_{stalk}=0.0001 C_{soil}=0.3445 D=0.0001 E=1.3694

CORRELATION COEFFICIENT=0.8412

MANHATTAN AGRICULTURAL EXPERIMENT

1980 CORN C-13
13.0 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
158	0.0759	0.0823	0.0223	0.	0.0600	0.237	0.315	0.218	0.181	0.036
161	0.0708	0.0900	0.0505	0.	0.0395	0.392	0.475	0.188	0.463	0.047
163		0.0935	0.0686	0.	0.0249	0.624	0.599	0.149	0.690	0.060
165	0.1107	0.0992	0.0847	0.	0.0144	0.678	0.738	0.110	0.941	0.076
168	0.1135	0.1085	0.1042	0.	0.0043	0.780	0.974	0.048	1.349	0.106
170	0.1274	0.1172	0.1142	0.	0.0030	0.808	1.149	0.044	1.634	0.130
171	0.1143	0.1204	0.1183	0.0001	0.0021	1.001	1.166	0.036	1.777	0.144
176	0.1517	0.1393	0.1325	0.0001	0.0067	1.263	1.394	0.239	2.494	0.218
178	0.1368	0.1400	0.1360	0.0001	0.0039	1.407	1.478	0.188	2.768	0.252
182	0.1683	0.1419	0.1404	0.0001	0.0014	1.496	1.631	0.107	3.273	0.327
189	0.1762	0.1466	0.1455	0.0001	0.0009	2.063	1.846	0.248	4.457	0.479
190	0.1786	0.1463	0.1455	0.0001	0.0007	2.060	1.871	0.189	4.446	0.500
192	0.1675	0.1461	0.1455	0.0001	0.0005	2.054	1.915	0.136	4.424	0.543
196	0.1552	0.1456	0.1453	0.0001	0.0002	2.347	1.984	0.043	4.356	0.637
198	0.1315	0.1470	0.1452	0.0001	0.0016	2.343	2.008	0.433	4.327	0.685
199		0.1462	0.1451	0.0001	0.0009	2.235	2.017	0.237	4.289	0.709
204	0.1265	0.1460	0.1450	0.0001	0.0010	2.170	2.038	0.228	4.235	0.831
206	0.1346	0.1454	0.1447	0.0001	0.0006	2.339	2.034	0.133	4.140	0.880
210	0.1368	0.1443	0.1436	0.0001	0.0005	2.305	2.006	0.088	3.863	0.975
212		0.1436	0.1428	0.0001	0.0006	2.384	1.982	0.092	3.684	1.022
213	0.1442	0.1432	0.1423	0.0001	0.0007	2.351	1.968	0.096	3.574	1.046
217	0.1169	0.1452	0.1394	0.0001	0.0056	2.300	1.895	0.491	3.137	1.136
218		0.1426	0.1383	0.0001	0.0041	2.326	1.871	0.316	3.009	1.157
220	0.1384	0.1403	0.1358	0.0002	0.0044	2.352	1.824	0.267	2.754	1.200
221	0.1247	0.1375	0.1342	0.0002	0.0032	2.345	1.798	0.173	2.616	1.220
224		0.1326	0.1278	0.0002	0.0046	2.285	1.712	0.164	2.204	1.281
225	0.1012	0.1303	0.1251	0.0002	0.0050	2.350	1.681	0.157	2.064	1.297
231	0.0964	0.1232	0.0991	0.0002	0.0238	2.359	1.473	0.335	1.227	1.402
240	0.0490	0.0426	0.0310	0.0002	0.0114	2.359	1.116	0.061	0.260	1.511
247	0.0929	0.0599	0.0099	0.0002	0.0498	2.356	0.832	0.207	0.077	1.550
254	0.0324	0.0290	0.	0.0001	0.0289	2.356	0.577	0.104	0.	1.541
268		0.0496	0.	0.0001	0.0495	2.199	0.309	0.165	0.	1.500

A_{leaf}=0.1482 B_{stalk}=0.0001 C_{soil}=0.3262 D=0.1202 E=0.9000

CORRELATION COEFFICIENT=0.8687

MANHATTAN AGRICULTURAL EXPERIMENT

1980 CORN C-13
17.0 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
158	0.0977	0.0971	0.0257	0.	0.0714	0.237	0.315	0.218	0.181	0.036
161	0.0912	0.1042	0.0581	0.	0.0461	0.392	0.475	0.188	0.463	0.047
163		0.1070	0.0789	0.	0.0281	0.624	0.599	0.149	0.690	0.060
165	0.1151	0.1134	0.0974	0.	0.0159	0.678	0.738	0.110	0.941	0.076
168	0.1245	0.1245	0.1199	0.	0.0045	0.780	0.974	0.048	1.349	0.106
170	0.1514	0.1344	0.1314	0.	0.0030	0.808	1.149	0.044	1.634	0.130
171	0.1406	0.1382	0.1361	0.0001	0.0020	1.001	1.166	0.036	1.777	0.144
176	0.1901	0.1584	0.1525	0.0001	0.0059	1.263	1.394	0.239	2.494	0.218
178	0.1862	0.1598	0.1564	0.0001	0.0033	1.407	1.478	0.188	2.768	0.252
182	0.1950	0.1627	0.1616	0.0001	0.0011	1.496	1.631	0.107	3.273	0.327
189	0.2099	0.1681	0.1675	0.0001	0.0006	2.063	1.846	0.248	4.457	0.479
190	0.1858	0.1680	0.1675	0.0001	0.0004	2.060	1.871	0.189	4.446	0.500
192	0.2051	0.1678	0.1674	0.0001	0.0003	2.054	1.915	0.136	4.424	0.543
196	0.1738	0.1674	0.1672	0.0001	0.0001	2.347	1.984	0.043	4.356	0.637
198	0.1611	0.1681	0.1671	0.0001	0.0008	2.343	2.008	0.433	4.327	0.685
199		0.1676	0.1670	0.0001	0.0005	2.235	2.017	0.237	4.289	0.709
204	0.1588	0.1674	0.1668	0.0001	0.0005	2.170	2.038	0.228	4.235	0.831
206	0.1439	0.1669	0.1665	0.0001	0.0003	2.339	2.034	0.133	4.140	0.880
210	0.1445	0.1657	0.1653	0.0001	0.0003	2.305	2.006	0.088	3.863	0.975
212		0.1648	0.1644	0.0001	0.0003	2.384	1.982	0.092	3.684	1.022
213	0.1387	0.1642	0.1637	0.0001	0.0004	2.351	1.968	0.096	3.574	1.046
217	0.1288	0.1637	0.1604	0.0001	0.0031	2.300	1.895	0.491	3.137	1.136
218		0.1616	0.1592	0.0001	0.0022	2.326	1.871	0.316	3.009	1.157
220	0.1291	0.1588	0.1563	0.0002	0.0024	2.352	1.824	0.267	2.754	1.200
221	0.1271	0.1563	0.1544	0.0002	0.0018	2.345	1.798	0.173	2.616	1.220
224		0.1500	0.1471	0.0002	0.0027	2.285	1.712	0.164	2.204	1.281
225	0.1186	0.1471	0.1440	0.0002	0.0029	2.350	1.681	0.157	2.064	1.297
231	0.1274	0.1295	0.1141	0.0002	0.0153	2.359	1.473	0.335	1.227	1.402
240	0.0339	0.0444	0.0356	0.0002	0.0085	2.359	1.116	0.061	0.260	1.511
247	0.0658	0.0536	0.0113	0.0002	0.0421	2.356	0.832	0.207	0.077	1.550
254	0.0302	0.0274	0.	0.0001	0.0272	2.356	0.577	0.104	0.	1.541
268		0.0529	0.	0.0001	0.0528	2.199	0.309	0.165	0.	1.500

A_{leaf}=0.1706 B_{stalk}=0.0001 C_{soil}=0.3932 D=0.3029 E=0.9000

CORRELATION COEFFICIENT=0.8809

MANHATTAN AGRICULTURAL EXPERIMENT

1980 CORN C-13
35.6 GHz HH

DATE	σ_{obs}	σ_{pred}	σ_{leaf}	σ_{stalk}	σ_{soil}	H	MP	MS	LAI	DWT
158	0.0692	0.0791	0.0409	0.	0.0381	0.237	0.315	0.218	0.181	0.036
161	0.0912	0.1135	0.0899	0.	0.0236	0.392	0.475	0.188	0.463	0.047
163		0.1336	0.1193	0.	0.0142	0.624	0.599	0.149	0.690	0.060
165	0.1746	0.1519	0.1440	0.	0.0078	0.678	0.738	0.110	0.941	0.076
168	0.1762	0.1739	0.1717	0.	0.0021	0.780	0.974	0.048	1.349	0.106
170	0.2275	0.1861	0.1847	0.	0.0014	0.808	1.149	0.044	1.634	0.130
171	0.2291	0.1907	0.1898	0.	0.0009	1.001	1.166	0.036	1.777	0.144
176	0.1959	0.2084	0.2057	0.0001	0.0027	1.263	1.394	0.239	2.494	0.218
178	0.2014	0.2106	0.2090	0.0001	0.0015	1.407	1.478	0.188	2.768	0.252
182		0.2136	0.2130	0.0001	0.0005	1.496	1.631	0.107	3.273	0.327
189	0.2344	0.2172	0.2168	0.0001	0.0003	2.063	1.846	0.248	4.457	0.479
190	0.2388	0.2171	0.2168	0.0001	0.0002	2.060	1.871	0.189	4.446	0.500
192	0.2518	0.2170	0.2168	0.0001	0.0001	2.054	1.915	0.136	4.424	0.543
196	0.2570	0.2168	0.2167	0.0001	0.	2.347	1.984	0.043	4.356	0.637
198	0.2203	0.2172	0.2166	0.0001	0.0005	2.343	2.008	0.433	4.327	0.685
199		0.2169	0.2166	0.0001	0.0003	2.235	2.017	0.237	4.289	0.709
204	0.1862	0.2168	0.2164	0.0001	0.0003	2.170	2.038	0.228	4.235	0.831
206	0.2377	0.2165	0.2163	0.0001	0.0002	2.339	2.034	0.133	4.140	0.880
210	0.1941	0.2158	0.2155	0.0001	0.0002	2.305	2.006	0.088	3.863	0.975
212		0.2153	0.2150	0.0001	0.0002	2.384	1.982	0.092	3.684	1.022
213	0.1626	0.2149	0.2145	0.0001	0.0003	2.351	1.968	0.096	3.574	1.046
217		0.2145	0.2122	0.0001	0.0022	2.300	1.895	0.491	3.137	1.136
218		0.2130	0.2112	0.0001	0.0016	2.326	1.871	0.316	3.009	1.157
220	0.1862	0.2109	0.2089	0.0001	0.0019	2.352	1.824	0.267	2.754	1.200
221	0.2056	0.2089	0.2073	0.0001	0.0014	2.345	1.798	0.173	2.616	1.220
224		0.2031	0.2007	0.0001	0.0022	2.285	1.712	0.164	2.204	1.281
225	0.1517	0.2003	0.1977	0.0002	0.0025	2.350	1.681	0.157	2.064	1.297
231	0.1585	0.1792	0.1648	0.0002	0.0142	2.359	1.473	0.335	1.227	1.402
240	0.0562	0.0648	0.0563	0.0002	0.0082	2.359	1.116	0.061	0.260	1.511
247	0.0689	0.0548	0.0183	0.0002	0.0363	2.356	0.832	0.207	0.077	1.550
254	0.0549	0.0208	0.	0.0001	0.0207	2.356	0.577	0.104	0.	1.541
268		0.0342	0.	0.0001	0.0341	2.199	0.309	0.165	0.	1.500

A_{leaf}=0.2181 B_{stalk}=0.0001 C_{soil}=0.2161 D=0.0624 E=1.1473

CORRELATION COEFFICIENT=0.9027

APPENDIX F. Growth Stages and Yields for 1979 and 1980 Fields

TABLE F.1

Wheat Growth Stages

Date	Feekes' Scale*	Stage
4/26/79	6.0	first node
5/01/79	7.0	second node
5/08/79	10.0	booting
5/16/79	10.4	heading 3/4 complete
5/22/79	10.53	flowering over at base of ear
5/29/79	10.54	anthesis complete
6/05/79	11.1	milk ripe
6/15/79	11.2	soft dough
6/22/79	11.3	caryopsis hard
6/29/79	11.4	caryopsis hard (ripe)

*See Large (1954) and Zodoks et al. (1974).

Harvested 7/2 and 7/3/79.

TABLE F.2

Corn Growth Stages

Date	Hanway Stage*	Stage
5/15/79		planted
5/23/79	0.0	emerged
5/25/79		one-leaf
5/28/79	0.5	two-leaf
5/31/79		three-leaf
6/04/79	1.0	four-leaf
6/11/79		five-leaf
6/14/79	1.5	six-leaf
6/26/79	2.5	nine-leaf
7/11/79	4.0	sixteen-leaf
7/19/79	5.0	pollen-shedding
7/31/79	6.0	blister
8/03/79	7.0	soft dough
8/30/79	9.0	dent

*See Hanway, J. J., 1971, "How a Corn Plant Develops," Special Report No. 48, Iowa State Univ. Cooperative Extension Services, Ames, Iowa.

Harvested 10/2/79.

TABLE F.3

Sorghum Growth Stage

Date	Vanderlip Stage*	Stage
5/17/79		planted
5/23/79	0	emerged
5/25/79		one-leaf
5/28/79		two-leaf
5/31/79	1	three-leaf
6/02/79		four-leaf
6/04/79	2	five-leaf
6/11/79		six-leaf
6/14/79		eight-leaf
6/26/79	3	nine-leaf
7/19/79	5	boot
7/31/79	7	soft dough
8/09/79	8	hard dough
8/30/79	9	physiological maturity

*See Vanderlip, R. L., 1972, "How a Sorghum Plant Develops," Contribution No. 1203, Agronomy Dept., Kansas Agricultural Experimental Station, Manhattan, Kansas 66502.

Harvested 9/14/79.

TABLE F.4

Growth Stage Summary for Corn

Date	Growth Stage*	Observations
5/20/80	planting	planting
5/24/80	0	emergence
6/02/80		three-leaf[t]
6/06/80	1.0	four-leaf
6/09/80		five-leaf
6/16/80	1.5	six-leaf
6/24/80		seven-leaf
7/07/80		eleven-leaf; began tasseling
7/10/80	5.0	thirteen-leaf; tasseling
7/24/80	6.0	blister stage
8/05/80	7.0	dough stage
8/08/80	8.0	beginning dent
8/18/80	9.0	fully dented
9/11/80		harvested

*See Hanway (1971).

[t]Number of expanded leaves.

TABLE F.5

Growth Stage Summary for Sorghum

Microwave Sorghum - 1980		
Date	Growth Stage*	Observations
5/21/80	planting	planting
5/28/80	0	emergence
6/02/80	1	three-leaf[t]
6/09/80		four-leaf
6/16/80	2	five-leaf
6/24/80		six-leaf
7/07/80		eight-leaf
7/10/80		nine-leaf
7/14/80	6	half bloom
7/31/80	7	soft dough
8/18/80	8	hard dough
9/11/80		harvested

*See Vanderlip (1972).

[t]Number of leaves with collar visible.

TABLE F.6

Crop-Yield Information

Year		Crop	Yield (kg/hectare)
1979	(Wheat)	W-41	4,020
		W-42	3,639
	(Corn)	C-11	7,020
		C-12	7,910
		C-13	6,253
		C-14	6,345
		C-15	7,428
		C-16	6,315
	(Sorghum)	S-31	5,584
		S-32	6,770
		S-33	6,970
		S-34	6,876
		S-35	7,028
		S-36	6,850
1980	(Corn)	C-11	5,284
		C-12	7,314
		C-13	4,856
	(Sorghum)	S-31	3,153
		S-32	3,859
		S-33	4,571

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